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FEASIBILITY MODEL OF A HIGH
RELIABILITY FIVE-YEAR TAPE TRANSPORT

Volume III - Appendices

IITRI Project No. E6225

Contract No. NAS5-21692 MOD. No. 1

Goddard Space Flight Center
Greenbelt, Maryland

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APPENDICES - VOLUME III

FEASIBILITY MODEL OF A HIGH RELIABILITY FIVE-YEAR TAPE TRANSPORT

(5 January 1972 - 5 November 1973)

Contract No. NAS5-21692

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October 1973

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APPENDIX A

ASSEMBLY DRAWINGS

A complete set of detail drawings were made of the "Five Year Tape Transport" and are available from NASA-GSFC. A list of these drawings by IITRI number is given in Table A-1.

TABLE A-1

DRAWING LIST FOR FIVE-YEAR TAPE TRANSPORT

DRAWING NUMBER	PART NAME	TOTAL QUANTITY	DESCRIPTION & SPECIFICATION
C-0100	Drive Capstan	1	
B-0101	Spring Cap	1	
B-0102	Tach. Bushing	1	
B-0103	Capstan Roller	1	
B-0104	Drive Capstan Shaft	1	
A-0105	Capstan Motor	1	Purchased Part
A-0106	Motor Ring	1	
A-0107	Retaining Key	1	
A-0108	Bearing/Roller Spacer	1	
A-0109	Capstan Spring Washer	1	
C-0110	Upper Housing	1	
C-0111	Lower Housing	1	
A-0112	Idler Bearing	2	Purchased Part
A-0113	Spring	1	Purchased Part
C-0125	Adj. Idler	2	
A-0126	Thrust Washer	1	
A-0127	Diff. Screw	1	
B-0128	Idler Housing	1	
B-0129	Crown Roller	1	
B-0130	Thrust Cap	1	
B-0131	Idler Shaft	1	
C-0150	Reel Assembly	1	
D-0151	Reel Base	1	
B-0152	Reel Shaft	1	
C-0153	Reel Hub	1	
C-0154	Bearing Housing	1	
A-0155	Reel Motor	1	Purchased Part

TABLE A-1 (continued)

DRAWING NUMBER	PART NAME	TOTAL QUANTITY	DESCRIPTION & SPECIFICATION
B-0156	Motor Ret. Ring	1	
B-0157	Bearing Spacer	1	
C-0158	Reel Flange	2	
B-0159	Brg. Ret. Ring	1	
B-0160	Bearing Cap	1	
B-0161	Spring Cap	1	
A-0162	Reel Bearing	2	Purchased Part
A-0163	V-Ring Seal	2	
D-0164	Mounting Deck	1	
B-0165	Deck Support Foot	4	
B-0166	Deck Cover	1	
D-0167	Deck Layout	---	
D-1000	Assembly Model - 5-Year Transport	---	

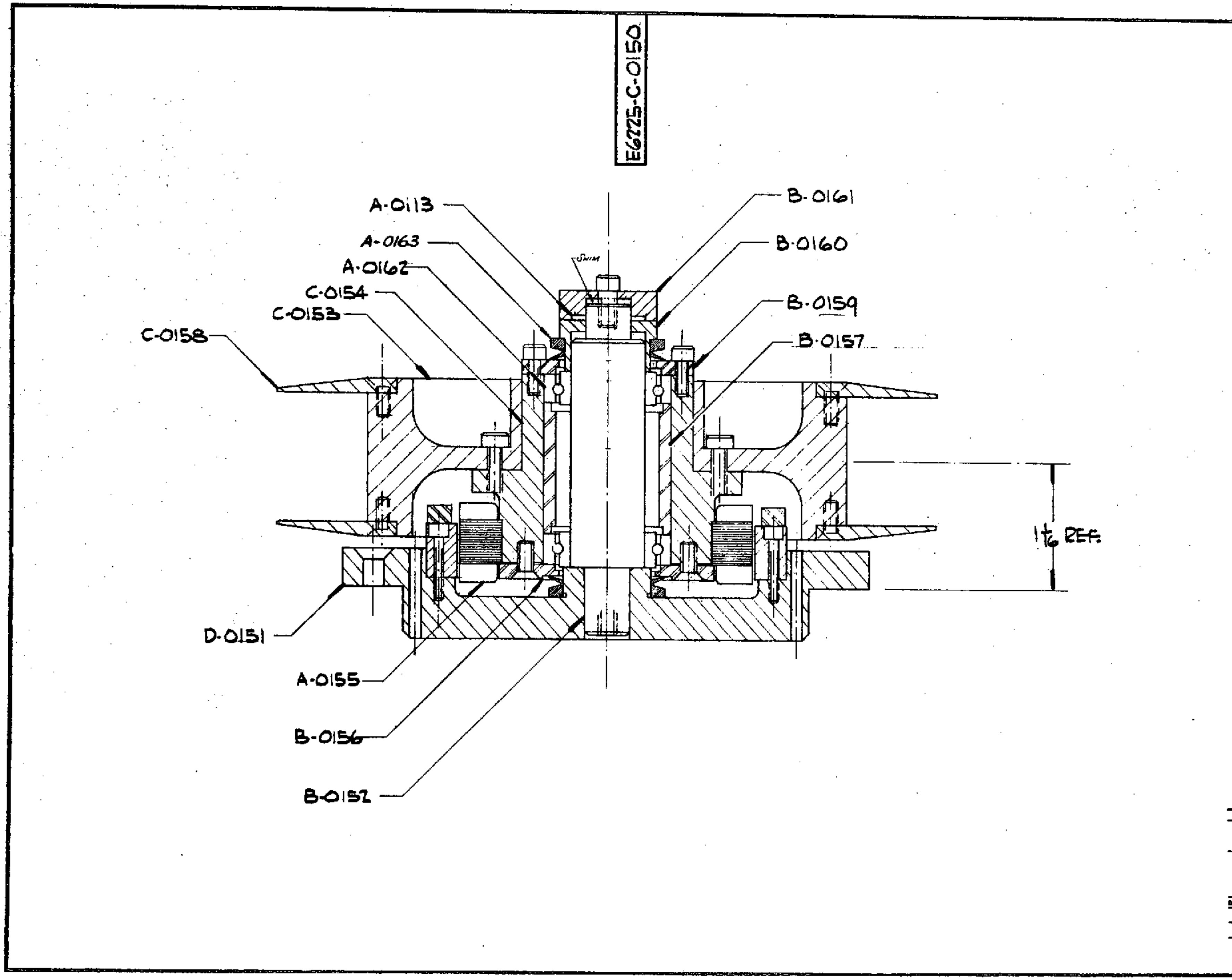


Figure A-1 REEL ASSEMBLY

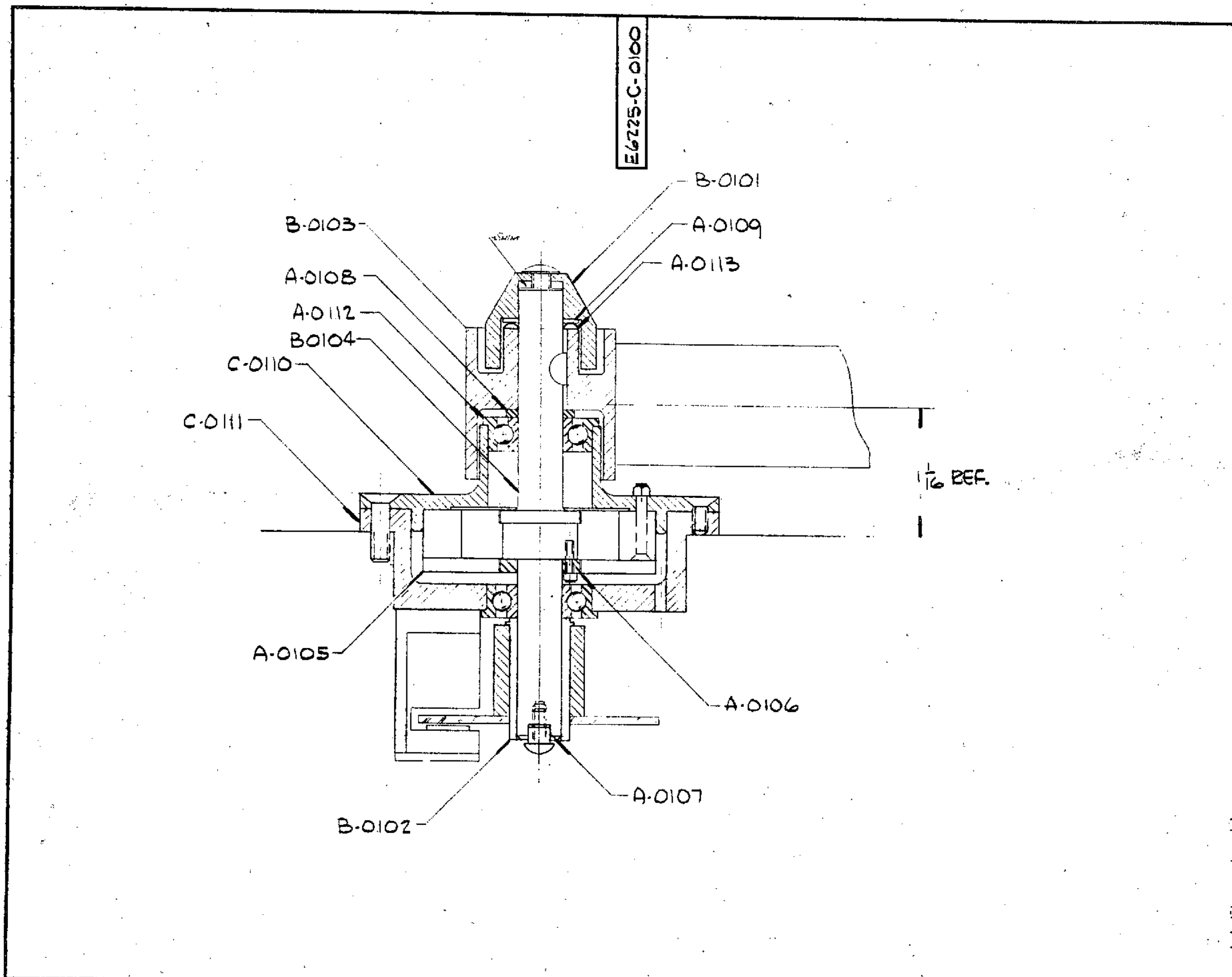


Figure A-2 DRIVE CAPSTAN

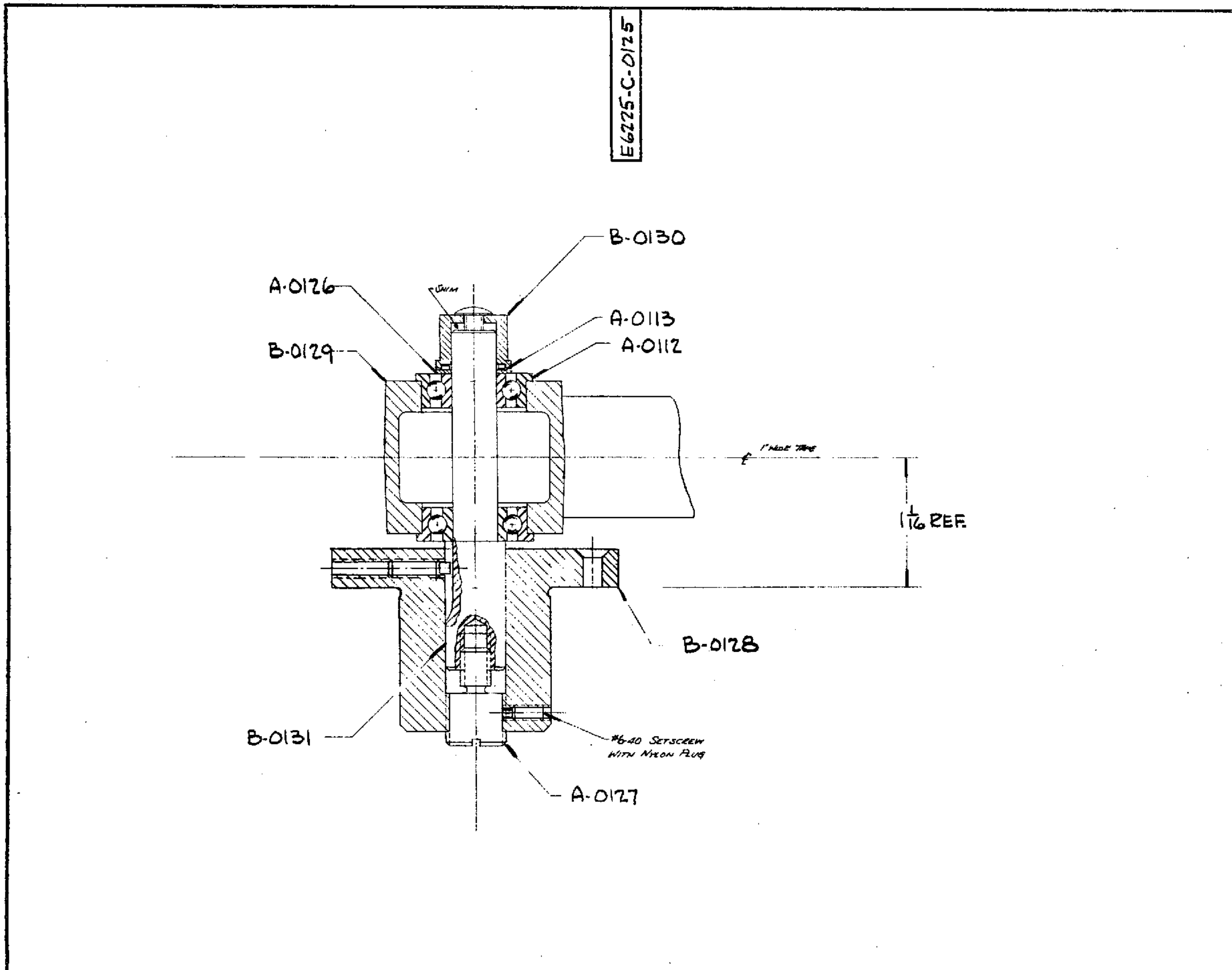


Figure A-3 ADJUSTABLE IDLER

APPENDIX B

TAPE GUIDANCE ANALYSIS

APPENDIX B

TAPE GUIDANCE ANALYSIS

Double Coned Roller

Consider a piece of tape (Figure B-1) contacting a double coned roller with its free end displaced by an amount S. The line of contact between the tape and the coned roller is assumed straight to simplify the analysis.

The tape is analyzed as two individual pieces of tape, divided by the roller center and contacting each half of the double coned roller at angles φ_1 and φ_2 where:

$$\varphi_1 = \gamma + \beta - y_o' \tag{1}$$

$$\varphi_2 = \gamma - \beta + y_o' \tag{2}$$

The angle γ is the angle the contact line normals (n_1 & n_2) make with the centerline of the roller. From Figure B-1 it can be seen that,

$$\tan \gamma = \frac{x_2 - x_1}{y} \tag{3}$$

for any point on the contact line a distance y from the center of the roller.

By the use of similar triangles,

$$\sin \psi_1 = \frac{x_1}{\frac{D - 2\,y \tan \alpha}{2}} = \frac{D - 2\,y \tan \alpha}{2L} \tag{4}$$

therefore,

$$x_1 = \frac{(D - 2\,y \tan \alpha)^2}{4L} \tag{5}$$

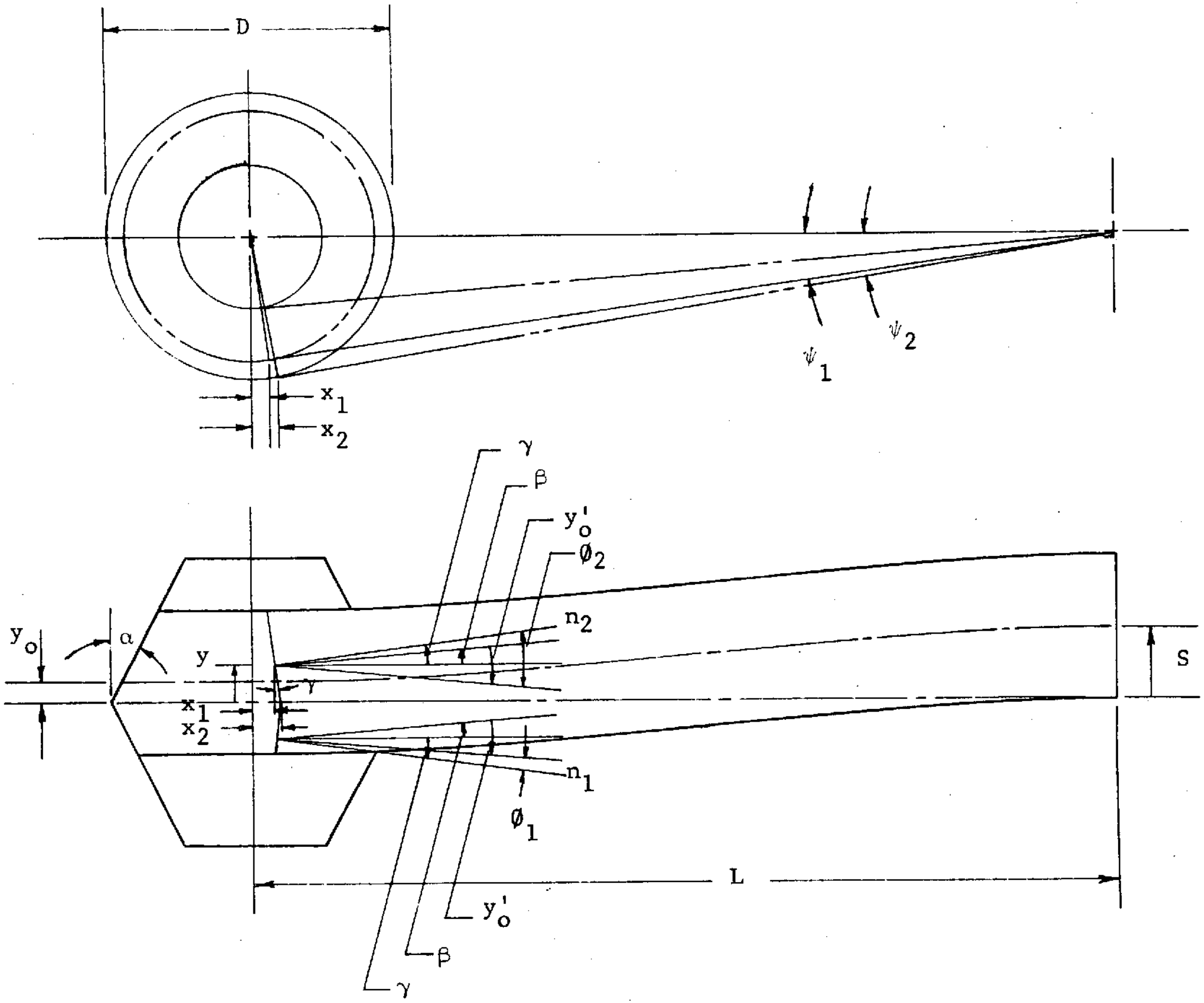


Figure B-1 TAPE CONTACT WITH DOUBLE CONE ROLLER

similarly,

$$\sin \psi_2 = \frac{x_2}{D/2} = \frac{D/2}{L} \tag{6}$$

and,

$$x_2 = \frac{D^2}{4L} \tag{7}$$

Substitution of equations (5) and (7) into equation (3) yields:

$$\tan \gamma = \frac{\frac{D^2}{4L} - \frac{(D - 2\ y \tan \alpha)^2}{4L}}{y} \tag{8}$$

If a small angle approximation ($\tan \alpha \simeq \alpha$) is used and α^2 terms neglected, equation (8) then becomes:

$$\gamma = \tan^{-1} \left(\frac{D\alpha}{L} \right) \tag{9}$$

The angle β is the angle between the centerline of the roller and the centerline of the tape assuming that the tape is undeformed when its free end is displaced. The angle β may be determined from geometry as,

$$\beta = \tan^{-1} \left(\frac{S - y_o}{L} \right) \tag{10}$$

The angle y_o' is the slope of the tape at the roller with respect to the undeformed tape centerline. In order to determine y_o' the tape is considered as a beam, fixed at $\frac{L}{2}$, and simply supported at the roller. The loading of the beam at the roller results from an unbalanced stress distribution in the tape, when the center of the tape is displaced from the center of the roller. The unbalanced stress distribution develops a restoring moment about the tape centerline. The slope of the tape is computed from the equation,

$$y_o' = \frac{M_c L}{8EI} \tag{11}$$

In order to analyze the action of the tape at the roller, the longitudinal stress distribution in the tape must first be determined. Assuming the longitudinal stress (or strain) depends only on roller geometry, the stress at any distance, y, from the center of the roller is given by:

$$\sigma(y) = \sigma_m + \sigma_r(y) \tag{12}$$

where:

$\sigma(y)$ = stress at any distance from the center of the roller

σ_m = stress at major diameter

$\sigma_r(y)$ = stress due to roller geometry

The stress due to roller geometry may be determined from the strain as expressed in the equation below.

$$\sigma_r(y) = \varepsilon_r(y)\ E = \left[\frac{r(y)\ \Delta\theta\ (y) - \frac{D}{2}\ \Delta\theta\ (y)}{\frac{D}{2}\ \Delta\theta\ (y)}\right]E \tag{13}$$

The roller radius for a double cone roller as a function of the distance from roller center $r(y)$ is given below. The small angle approximation of $\tan\alpha \simeq \alpha$ is made in deriving this equation.

$$r(y) = \frac{D}{2} - y\alpha \quad \text{(double cone)} \tag{14}$$

Substituting equation (14) into (13) and neglecting changes in the wrap angle $\Delta\theta$ (y) for changes in y, equation (12) becomes,

$$\sigma(y) = \sigma_m - \frac{2y\alpha E}{D} \tag{15}$$

Refering to Figure B-2, the resultant force developed at the roller, which must equal the tape tension (T) for equilibrium,

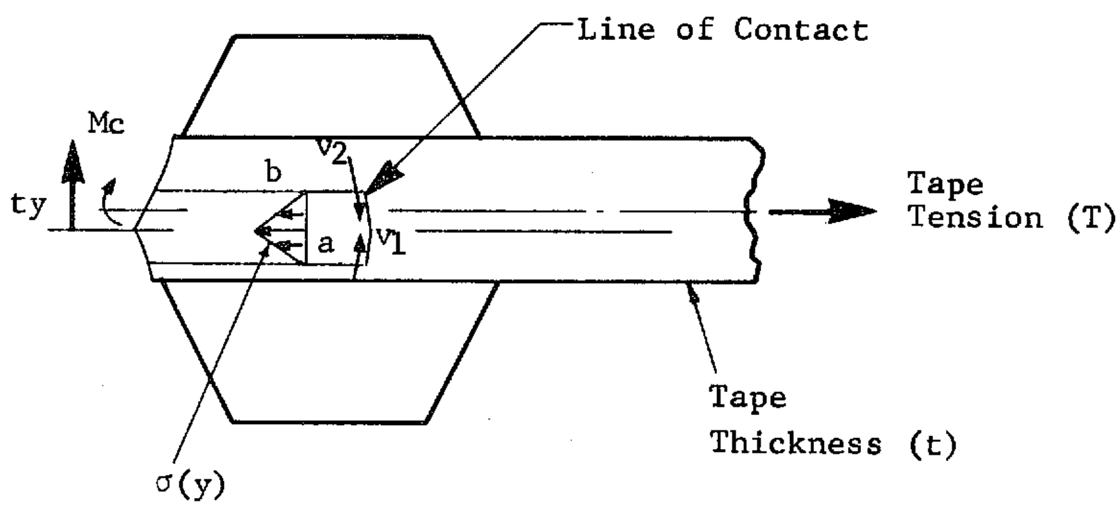


FIGURE B-2 RESULTANT FORCES AND MOMENTS IN TAPE PASSING OVER A DOUBLE CONED ROLLER

may be determined by integration of the stress distribution between the limits (a,b) of tape contact.

$$T = \int_a^b \sigma(y)\ t\ dy = \int_a^b \left(\sigma_m - \frac{2y\alpha E}{D}\right) t\ dy \qquad (16)$$

Since the stress at the major diameter (σ_m) and the limits of contact (a and b) are unknown, an iterative procedure must be used. Hence, the stress distribution integrated between the limits of tape contact equals the tape tension (equation 16). Furthermore the stress at the limits of contact is equal to zero, provided the contact width is less than the tape width, that is:

$$\sigma(a) = 0 \text{ if } a > y_o - \frac{W}{2} \qquad (17)$$

$$\sigma(b) = 0 \text{ if } b < y_o + \frac{W}{2} \qquad (18)$$

The stress distribution at the roller is resolved into a moment about the center of the tape and a tangential force acting in the direction of the line contact. Thus,

$$M_c = \int_a^b (y_o - y)\ \sigma\ (y)\ t\ dy \qquad (19)$$

$$V_1 = \int_a^o \sigma(y)\ \sin\ \varphi_1\ t\ dy \qquad (20)$$

$$V_2 = \int_a^b \sigma(y)\ \sin\ \varphi_2\ t\ dy \qquad (21)$$

The tape moves as a result of the unbalanced tangential forces on either side of roller center. The direction of movement is in the direction of largest tangential force. A non-slip condition is assumed to exist on the side having the greatest tangential force. The side with the least force

is assumed to slide without resistance. As the tape is advanced by dx, it is screwed over an amount Δy_o at the helix angle ϕ on the side with the largest shear force where,

$$\Delta y_o = dx \sin \phi \tag{22}$$

With the tape displaced by an amount Δy_o from its previous position, the moment about the center of the tape and the tangential force components are again calculated. If the tangential forces are not balanced on either side of the roller, the tape is again screwed over Δy_o as defined by equation (22).

For a constant displacement of the free end, S, the procedure is repeated until equilibrium is reached.

The free end of tape may also be given a harmonic disturbance defined by:

$$S = A_i \sin \frac{2\pi x}{\lambda} \tag{23}$$

where:

A_i = peak amplitude of the disturbance, in.

λ = wavelength of the disturbance, in.

x = amount of tape advanced, in.

Since equilibrium cannot be obtained with a sinusoidal input disturbance, attenuation of the input amplitude A_i to the peak output amplitude A_o is computed as follows:

$$\text{Attenuation} = \left(1 - \frac{A_o}{A_i}\right) 100 \tag{24}$$

Spherically Crowned Roller

The longitudinal stress distribution for a spherically crowned roller can also be expressed by equations 12 and 13.

The expression for the radius of a spherical roller at any distance y is,

$$r(y) = \frac{D}{2} - \rho \left[1 - \sqrt{1 - (y/\rho)^2} \right] \quad \text{(spherical)} \qquad (25)$$

Substituting into equation (13) and neglecting changes in wrap angle $\Delta\theta$ (y) yields,

$$\sigma(y) = \sigma_m - \frac{2\rho E}{D} \left[1 - \sqrt{1 - (y/\rho)^2} \right] \qquad (26)$$

which is the expression for the stress distribution over a spherically crowned roller.

The analysis of a spherical roller is similar to that for the double cone, except that the contact line can no longer be approximated by a straight line. The angle γ , which is the angle the contact line normally makes with the centerline of the roller, is no longer constant on either side of the roller.

Referring to Figure B-3, the angle γ can, however, be defined as:

$$\tan \gamma = \frac{x_2 - x_1}{y} \qquad (27)$$

at any distance y from the center of the roller. Also, by similar triangles,

$$\sin \psi_1 = \frac{x_1}{\frac{D}{2} - \frac{y^2}{2\rho}} = \frac{\frac{D}{2} - \frac{y^2}{2\rho}}{L} \qquad (28)$$

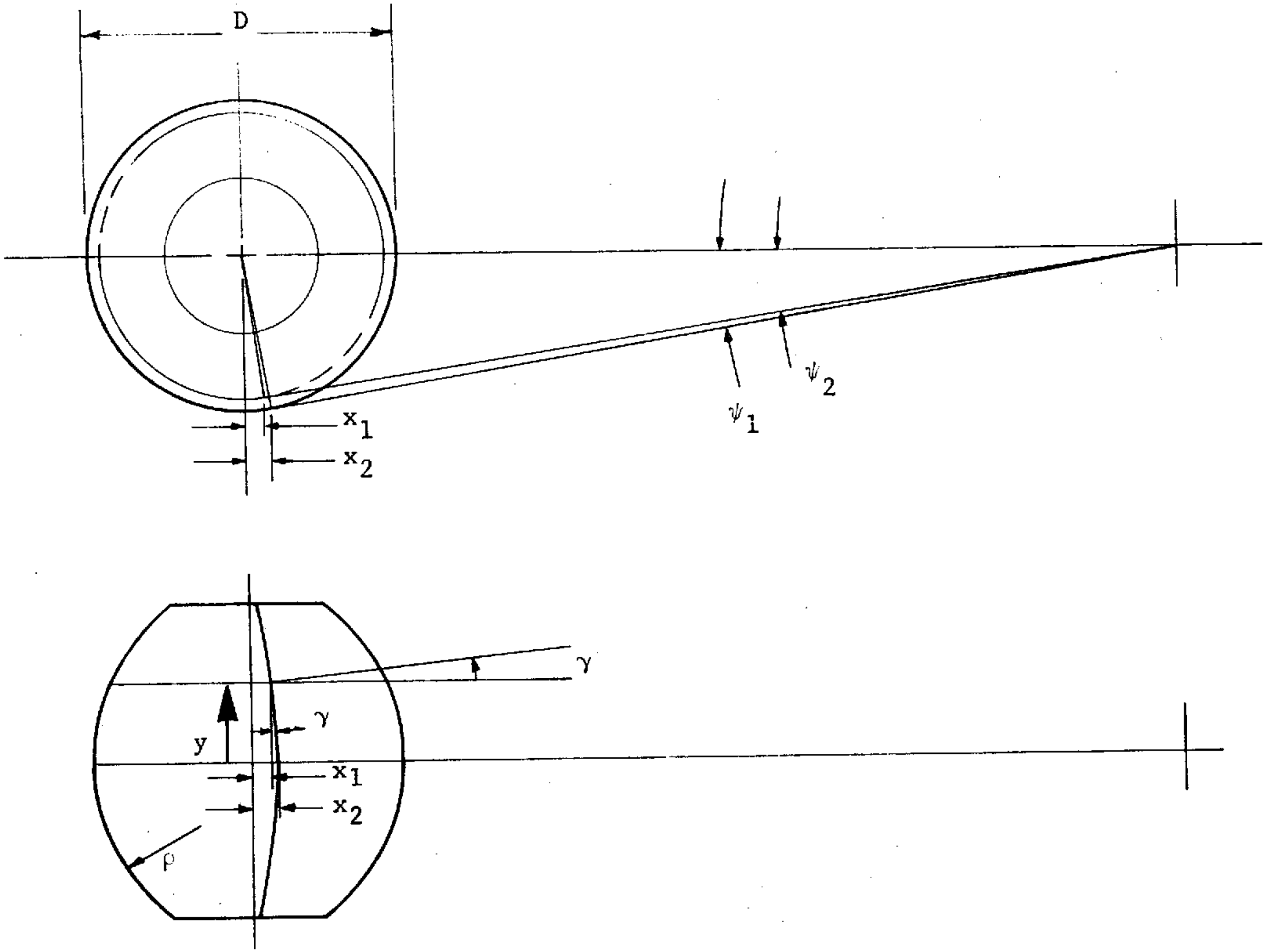


Figure B-3
SPHERICALLY CROWNED ROLLER

and,

$$x_1 = \frac{\left(\frac{D}{2} - \frac{y^2}{2\rho}\right)^2}{L} \tag{29}$$

similarly,

$$\sin \psi_2 = \frac{x_2}{\frac{D}{2}} = \frac{\frac{D}{2}}{L} \tag{30}$$

and

$$x_2 = \frac{D^2}{4L} \tag{31}$$

Substitution of equation (29) and (31) into equation (27) yields:

$$\gamma = \tan^{-1} \left[\frac{1}{\rho L} \left(\frac{Dy}{2} - \frac{y^3}{4\rho}\right) \right] \tag{32}$$

Instead of two pieces of tape divided at the roller center, the tape contacting a spherical roller is divided into numerous pieces of width dy. The moment about the center of the tape and the tangential force components are calculated as before except the angle γ is now a function of position on the roller in the expressions for φ_1 and φ_2.

The tape is assumed to move laterally in the direction of largest tangential force as before, although the helix angle φ used in equation 22 is defined as the average $\emptyset$ angle on the side with the largest tangential force, i.e.,

$$\bar{\varphi} = \frac{1}{N} \sum_{i=1}^{N} \varphi_i \tag{33}$$

Guidance Program

The preceding tape guidance analysis is programmed in the Fortran IV language. The input data specifications are given in Table B-1. A logic flow diagram for the program is shown in Figure B-4. A print of the program, the input data list, and a typical output listing are given in Figures B-5, B-6 and B-7, respectively.

Table B-1

INPUT DATA SPECIFICATION

Card Number	Variable Name	Description	Field Width	Format	Units
1	D	Major diameter	1-10	F 10.0	in.
	T	Tension	11-20	"	oz.
	W	Tape width	21-30	"	in.
	R	Crown Radius(R=0.0 for double coned)	31-40	"	in.
	DALPHA	Cone angle(DALPHA=0.0 for spherical)	41-50	"	deg.
2	TC	Oxide thickness	1-20	F 10.0	in.
	TM	Mylar thickness	11-20	"	in.
	EC	Oxide elastic modulus	21-30	"	psi.
	EM	Mylar elastic modulus	31-40	"	psi.
3	AI	Offset or amplitude for harmonic disturbance	1-20	F 10.0	in.
	LAM	Wavelength of harmonic disturbance (LAM = 0.0 for constant offset)	11-20	"	in.
	LENGTH	Tape lead-in length	21-30	"	in.
	DX	Step size in length direction	31-40	"	in.
	DY	Step size in width direction	41-50	"	in.
	XMAX	Tape length passed over roller	51-60	"	in.
	NPRT	Print interval	61-70	I 10	--

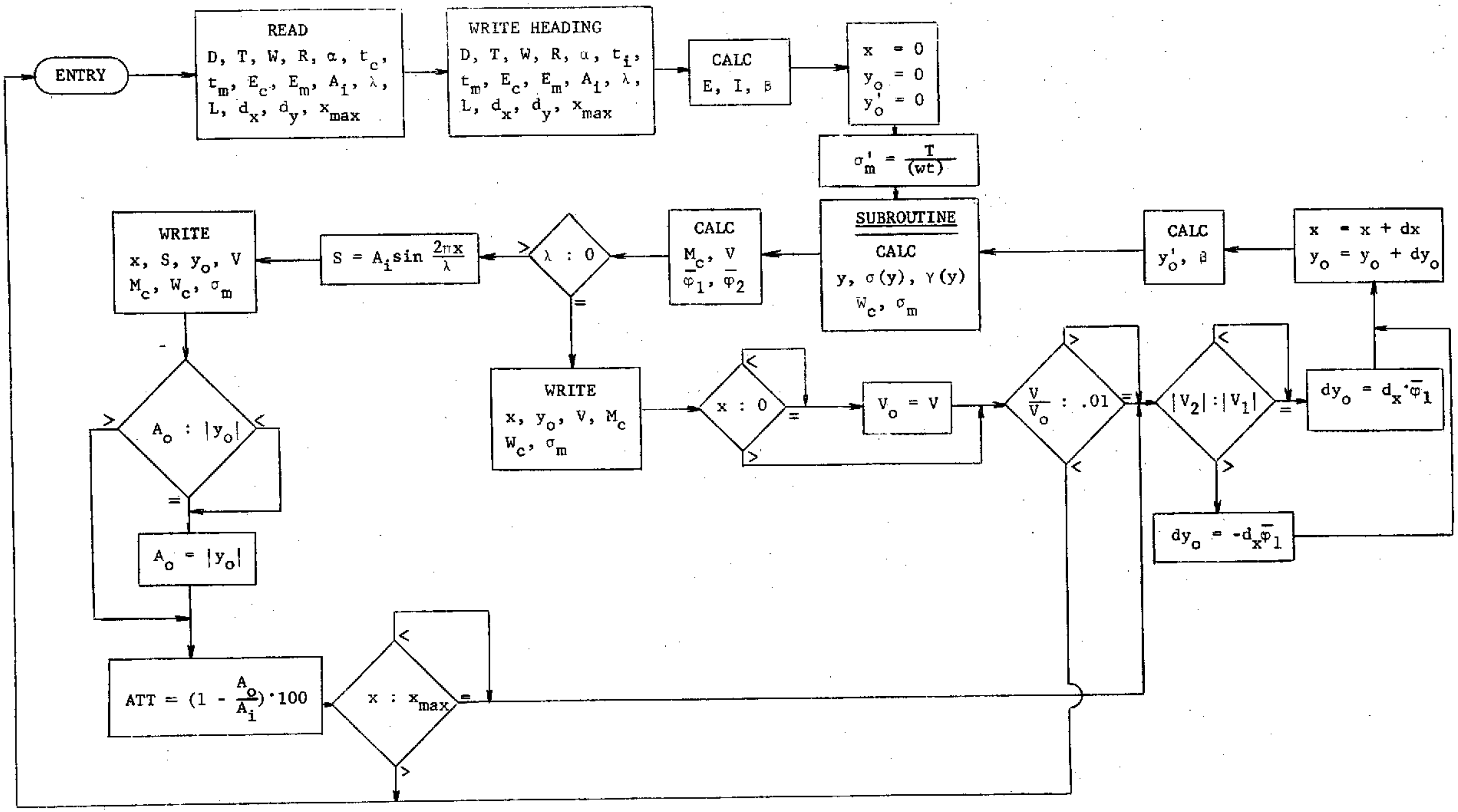


Figure B-4 FLOW CHART FOR GUIDANCE PROGRAM

```
      REAL LENGTH,I,MC,LAM
      DIMENSION Y(500),SIG(500),GAM(500)
    1 READ(5,2)D,T,W,R,DALPHA,TC,TM,EC,EM,S,LAM,LENGTH,DX,DY,XMAX,NPRT
    2 FORMAT(5F10.0/4F10.0/6F10.0,I10)
      WRITE(6,3)
    3 FORMAT(1H1,5X,40H CROWNED GUIDE ROLLER TRANSIENT ANALYSIS////)
      IF(LAM.LT.10.E-4) GO TO 4
      WRITE(6,15)
   15 FORMAT(5X,15H HARMONIC INPUT////)
      GO TO 5
    4 WRITE(6,10)
   10 FORMAT(5X,16H CONSTANT OFFSET////)
    5 IF(R.LT.10.E-4) GO TO 17
      WRITE(6,18)
   18 FORMAT(5X,17H SPHERICAL ROLLER////)
      WRITE(6,26)T,W,D,R
   26 FORMAT(5X,20H PHYSICAL PARAMATERS///
     1 8X,13H TAPE TENSION,T40,F10.2,2X,4H OZ.,/
     2 8X,11H TAPE WIDTH,T40,F10.3,2X,4H IN.,/
     3 8X,16H ROLLER DIAMETER,T40,F10.3,2X,4H IN.,/
     4 8X,13H CROWN RADIUS,T40,F10.2,2X,4H IN.//)
      GO TO 19
   17 WRITE(6,11)
   11 FORMAT(5X,20H DOUBLE CONED ROLLER////)
      WRITE(6,12)T,W,D,DALPHA
   12 FORMAT(5X,20H PHYSICAL PARAMATERS///
     1 8X,13H TAPE TENSION,T40,F10.2,2X,4H OZ.,/
     2 8X,11H TAPE WIDTH,T40,F10.3,2X,4H IN.,/
     3 8X,16H ROLLER DIAMETER,T40,F10.3,2X,4H IN.,/
     4 8X,11H CONE ANGLE,T40,F10.2,2X,5H DEG.//)
   19 WRITE(6,13)TC,TM,EC,EM
   13 FORMAT(5X,16H TAPE PROPERTIES///
     1 8X,16H OXIDE THICKNESS,T40,F10.5,2X,4H IN.,/
     2 8X,16H MYLAR THICKNESS,T40,F10.5,2X,4H IN.,/
     3 8X,22H OXIDE ELASTIC MODULUS,T40,F10.0,2X,4H PSI,/
     4 8X,22H MYLAR ELASTIC MODULUS,T40,F10.0,2X,4H PSI//)
      IF(LAM.LT.10.E-4) GO TO 6
      WRITE(6,16)S,LAM,LENGTH,DX,DY,XMAX
   16 FORMAT(5X,20H GUIDANCE PARAMATERS///
     1 8X,16H INPUT AMPLITUDE,T40,F10.3,2X,4H IN.,/
     2 8X,12H WAVE LENGTH,T40,F10.3,2X,4H IN.,/
     3 8X,15H LEAD-IN LENGTH,T40,F10.3,2X,4H IN.,/
     4 8X,19H STEP SIZE (LENGTH),T40,F10.3,2X,4H IN.,/
     5 8X,18H STEP SIZE (WIDTH),T40,F10.3,2X,4H IN.,/
     6 8X,15H MAXIMUM LENGTH,T40,F10.3,2X,4H IN.//)
      WRITE(6,53)
   53 FORMAT(1H1,5X,12H TAPE TRAVEL,T25,6H INPUT,T39,7H OUTPUT,T55,
     1 6H SHEAR,T69,7H MOMENT,T81,14H CONTACT WIDTH,T100,5H MAX.,/
     2 T23,10H AMPLITUDE,T37,10H AMPLITUDE,T99,7H STRESS,/T10,6H (IN.),
     3 T25,6H (IN.),T40,6H (IN.),T55,6H (LBS),T68,9H (LBS-IN),T85,
     4 6H (IN.),T100,6H (PSI)//)
      GO TO 7
```

Figure B-5

Tape Guidance Program

Page 1 of 3

```
      6 WRITE(6,14)S,LENGTH,DX,DY,XMAX
     14 FORMAT(5X,20H GUIDANCE PARAMATERS///
       1 8X,7H OFFSET,T40,F10.3,2X,4H IN.,/
       2 8X,15H LEAD-IN LENGTH,T40,F10.3,2X,4H IN.,/
       3 8X,19H STEP SIZE (LENGTH),T40,F10.3,2X,4H IN.,/
       4 8X,18H STEP SIZE (WIDTH),T40,F10.3,2X,4H IN.,/
       5 8X,15H MAXIMUM LENGTH,T40,F10.3,2X,4H IN.//)
        WRITE(6,50)
     50 FORMAT(1H1,5X,12H TAPE TRAVEL,T26,6H SHIFT,T40,6H SHEAR,T54,
       1 7H MOMENT,T66,14H CONTACT WIDTH,T81,12H MAX. STRESS,/
       2 T10,5H (IN.),T26,6H (IN.),T40,6H (LBS),T53,9H (LBS-IN),T70,
       3 6H (IN.),T85,6H (PSI)//)
      7 T=T/16.
        ALPHA=DALPHA/57.296
        THK=TM+TC
        E=(EM*TM+EC*TC)/THK
        I=W**3*THK/12.
        PI=3.14159
        AI=0.0
        AO=0.0
        IF(LAM.LT.10.E-4) AI=S
        BETA=AI/LENGTH
        X=0.0
        YO=0.0
        YOP=0.0
        NX=NPRT
        K=0
        SIGM=T/(W*THK)
     99 CALL STRESS(D,T,W,R,ALPHA,LENGTH,E,YO,DY,THK,Y,SIG,GAM,N,WC,SIGM)
        MC=0.0
        V1=0.0
        V2=0.0
        PHI1A=0.0
        PHI2A=0.0
        DO 20 J=1,N
        MC=MC+(YO-Y(J))*SIG(J)*DY*THK
        IF(Y(J).GT.0.0) GO TO 21
        PHI1=GAM(J)+BETA-YOP
        PHI1A=PHI1A+PHI1
        V1=V1+SIG(J)*PHI1*DY*THK
        GO TO 20
     21 PHI2=GAM(J)-BETA+YOP
        PHI2A=PHI2A+PHI2
        V2=V2-SIG(J)*PHI2*DY*THK
     20 CONTINUE
        PHI1A=PHI1A/N
        PHI2A=PHI2A/N
        V=V1+V2
        IF(NX.NE.NPRT) GO TO 24
        IF(LAM.LT.10.E-4) GO TO 23
        WRITE(6,51) X,AI,YO,V,MC,WC,SIGM
     51 FORMAT(F15.3,4F15.5,F15.3,F15.1)
        NX=0
        IF(YO.GT.AO) AO=YO
        ATT=(1.-AO/S)*100.
        IF(X.GE.XMAX) GO TO 25
        GO TO 24
     23 WRITE(6,52)X,YO,V,MC,WC,SIGM
     52 FORMAT(2F15.3,2F15.5,F15.3,F15.1)
        NX=0
```

```
      IF(X.LT.10.E-4) VO=V
      IF(ABS(V/VO).LE.0.01) K=K+1
      IF(K.EQ.5) GO TO 22
      IF(X.GE.XMAX) GO TO 30
   24 X=X+DX
      NX=NX+1
      AI=S*SIN(2.*PI*X/LAM)
      IF(LAM.LT.10.E-4) AI=S
      DYO=DX*PHI1A
      IF(ABS(V2).GT.ABS(V1)) DYO=-DX*PHI2A
      YO=YO+DYO
      YOP=(MC*LENGTH)/(8.*E*I)
      BETA=(AI-YO)/LENGTH
      GO TO 99
   22 WRITE(6,54)S,YO
   54 FORMAT('0',5X,6H FOR A,F5.3,28H OFFSET, THE TAPE REACHED AN
     1 15H EQUILIBRIUM AT,F5.3,35H (IN) FROM THE CENTER OF THE ROLLER/)
      GO TO 30
   25 WRITE(6,55)X,ATT
   55 FORMAT('0',5X,6H AFTER,F7.3,34H INCHES OF TAPE,THE ATTENUATION IS
     1 ,F6.2,8H PERCENT)
   30 CONTINUE
      GO TO 1
      END
```

```
      SUBROUTINE STRESS(D,T,W,R,ALPHA,LENGTH,E,YO,DY,THK,Y,SIG,GAM,N,
     1 WC,SIGM)
      REAL LENGTH
      DIMENSION Y(500),SIG(500),GAM(500)
  100 IF(R.LT.10.E-4) GO TO 101
      C=(D*SIGM)/(R*E)
      A=-R*SQRT(C-C*C/4.)
      GO TO 102
  101 A=(-D*SIGM)/(2.*E*ALPHA)
  102 B=-A
      IF(A.LT.YO-W/2.) A=YO-W/2.
      IF(B.GT.YO+W/2.) B=YO+W/2.
      WC=B-A
      N=WC/DY
      P=0.0
      DO 103 J=1,N
      Y(J)=A+DY/2.+(J-1)*DY
      IF(R.LT.10.E-4) GO TO 104
      SIG(J)=SIGM-2.*R*E/D*(1.-SQRT(1.-(Y(J)/R)**2))
      GAM(J)=(D*ABS(Y(J)))/(2.*R*LENGTH)
      GO TO 106
  104 SIG(J)=SIGM-(2.*E*ALPHA*ABS(Y(J))/D)
      GAM(J)=D*ALPHA/LENGTH
  106 P=P+SIG(J)*DY*THK
  103 CONTINUE
      IF(ABS(T-P).LT.0.01*T) GO TO 111
      SIGM=SIGM+(T-P)/(WC*THK)
      GO TO 100
  111 CONTINUE
      RETURN
      END
```

CROWNED GUIDE ROLLER TRANSIENT ANALYSIS

HARMONIC INPUT

DOUBLE CONED ROLLER

PHYSICAL PARAMATERS

TAPE TENSION	10.00	OZ.
TAPE WIDTH	1.000	IN.
ROLLER DIAMETER	1.500	IN.
CONE ANGLE	2.00	DEG.

TAPE PROPERTIES

OXIDE THICKNESS	.00020	IN.
MYLAR THICKNESS	.00092	IN.
OXIDE ELASTIC MODULUS	100000.	PSI
MYLAR ELASTIC MODULUS	650000.	PSI

GUIDANCE PARAMATERS

INPUT AMPLITUDE	.020	IN.
WAVE LENGTH	4.000	IN.
LEAD-IN LENGTH	4.280	IN.
STEP SIZE (LENGTH)	.100	IN.
STEP SIZE (WIDTH)	.010	IN.
MAXIMUM LENGTH	20.000	IN.

Figure B-6

Input Data to Tape Guidance Program

TAPE TRAVEL (IN.)	INPUT AMPLITUDE (IN.)	OUTPUT AMPLITUDE (IN.)	SHEAR (LBS)	MOMENT (LBS-IN)	CONTACT WIDTH (IN.)	MAX. STRESS (PSI)
.000	.00000	.00000	.00026	.00006	.295	3789.8
.200	.00618	.00130	.00097	.00087	.295	3789.8
.400	.01176	.00271	.00157	.00175	.295	3789.8
.600	.01618	.00421	.00199	.00269	.295	3789.8
.800	.01902	.00577	.00217	.00367	.295	3789.8
1.000	.02000	.00735	.00208	.00466	.295	3789.8
1.200	.01902	.00891	.00170	.00563	.295	3789.8
1.400	.01618	.01039	.00106	.00656	.295	3789.8
1.600	.01176	.01175	.00021	.00742	.295	3789.8
1.800	.00618	.01175	-.00061	.00741	.295	3789.8
2.000	.00000	.01041	-.00131	.00657	.295	3789.8
2.200	-.00618	.00896	-.00200	.00567	.295	3789.8
2.400	-.01176	.00741	-.00258	.00469	.295	3789.8
2.600	-.01618	.00577	-.00298	.00367	.295	3789.8
2.800	-.01902	.00408	-.00314	.00261	.295	3789.8
3.000	-.02000	.00238	-.00303	.00154	.295	3789.8
3.200	-.01902	.00070	-.00264	.00050	.295	3789.8
3.400	-.01618	-.00090	-.00198	-.00051	.295	3789.8
3.600	-.01176	-.00240	-.00111	-.00144	.295	3789.8
3.800	-.00618	-.00375	-.00009	-.00229	.295	3789.8
4.000	-.00000	-.00372	.00082	-.00227	.295	3789.8
4.200	.00618	-.00233	.00151	-.00140	.295	3789.8
18.800	-.01902	.00232	-.00288	.00151	.295	3789.8
19.000	-.02000	.00066	-.00277	.00047	.295	3789.8
19.200	-.01902	-.00098	-.00238	-.00056	.295	3789.8
19.400	-.01618	-.00254	-.00173	-.00154	.295	3789.8
19.600	-.01176	-.00400	-.00087	-.00245	.295	3789.8
19.800	-.00618	-.00532	.00015	-.00327	.295	3789.8
20.000	-.00000	-.00404	.00087	-.00247	.295	3789.8
20.200	.00618	-.00264	.00156	-.00160	.295	3789.8

AFTER 20.200 INCHES OF TAPE,THE ATTENUATION IS 41.24 PERCENT

Figure B-7

Output Data to Tape Guidance Program

APPENDIX C

TAPE STRESSES OVER CROWNED ROLLERS

APPENDIX C

TAPE STRESSES OVER CROWNED ROLLERS

Many magnetic tape recorders use crowned rollers to stabilize and guide the tape during the record and to reproduce operating modes. The resulting mechanical stresses introduced into the tape, as a result of bending around these crowned rollers, is of interest to the tape transport designer. Extremely high stresses can severely damage the tape and degrade its useful life. Consequently, an analytical computer program was developed which allows the rapid and accurate calculation of mechanical stress within the tape. This appendix presents a general discussion of the computational procedure used, the range of capability, the computer program, and the input/output requirements.

Consider a typical tape roller element as shown in Figure C-1. The tape is under tension and wrapped around a crowned roller. Stresses are developed within the tape due to:

- tape tension
- bending in the axial tape direction
- bending in the lateral tape direction

Furthermore, the stress components can be computed separately and combined using the principal of superposition.

Two points should be noted concerning the behavior of the tape. First, the tape does not necessarily maintain contact with the roller across the entire width of the tape. Since the tape can support very little compressive force, the stresses in the non-contacting portion are assumed to be zero.

Secondly, the axial strain distribution or profile is only dependent upon the geometry of the roller. Since elastic behavior is assumed, the stress profile is also dependent upon

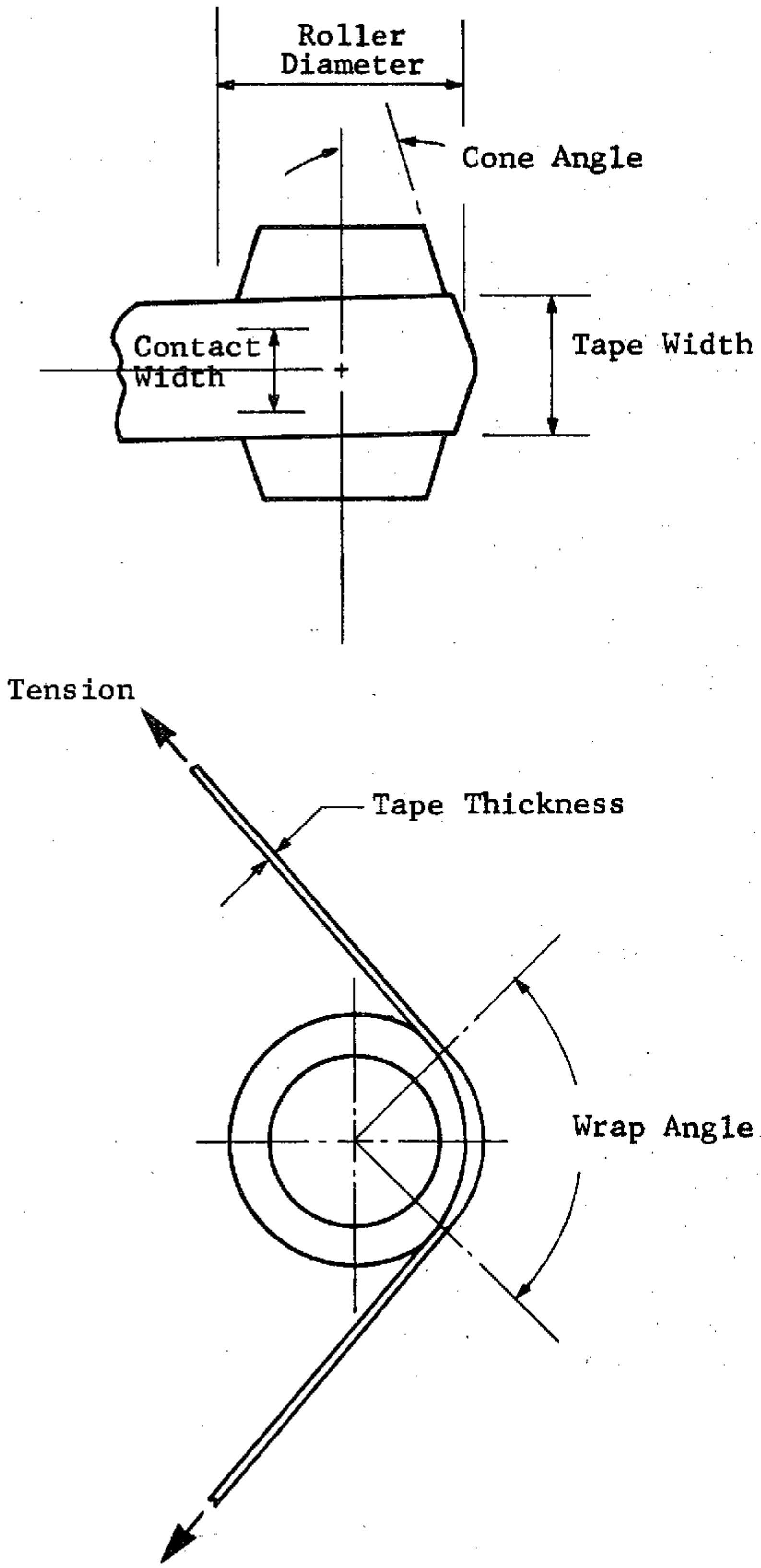


Figure C-1 TAPE ROLLER SYSTEM

the roller geometry. It should also be noted that the stress or strain developed is not dependent upon the magnitude of the wrap angle.

The computer program uses an iterative procedure to determine the axial stress distribution across the contact width of the tape. Thus, a stress distribution is assumed consistent with the roller geometry. The tensile force resulting from the integration of the stress distribution must then equal the total tape tension. In this way, the contact width and stress magnitude are determined.

The program considers the tape as a bilayer elastic beam, i.e., one layer is the base material (mylar) and the second layer is the oxide coating. Hence the program accounts for the different thicknesses and elasticities of these materials. In addition, the Poisson effect due to lateral bending is included in the calculation of the axial tensile stresses.

Four basic types of crowned rollers may be stress analyzed with the program. These rollers, shown in Figure C-2, are defined by specifying zero or positive values for the variables R (spherical radius) and α (cone angle). In addition, the oxide side of the tape may be defined to be against the roller (I = 1) or away from the roller (I = 0) by specifying the proper value of the integer.

Program Input/Output

The input data necessary for program execution is entered on two data cards as shown in Table C-1. The variable names, descriptions and formats are as shown.

A complete program listing is shown as Figure C-3. The program is written in the Fortran IV language.

A typical output sheet showing the format is given in Figure C-4. The physical parameters and tape properties entered are listed for easy verification. The actual computed width of tape in surface contact with the roller is listed next.

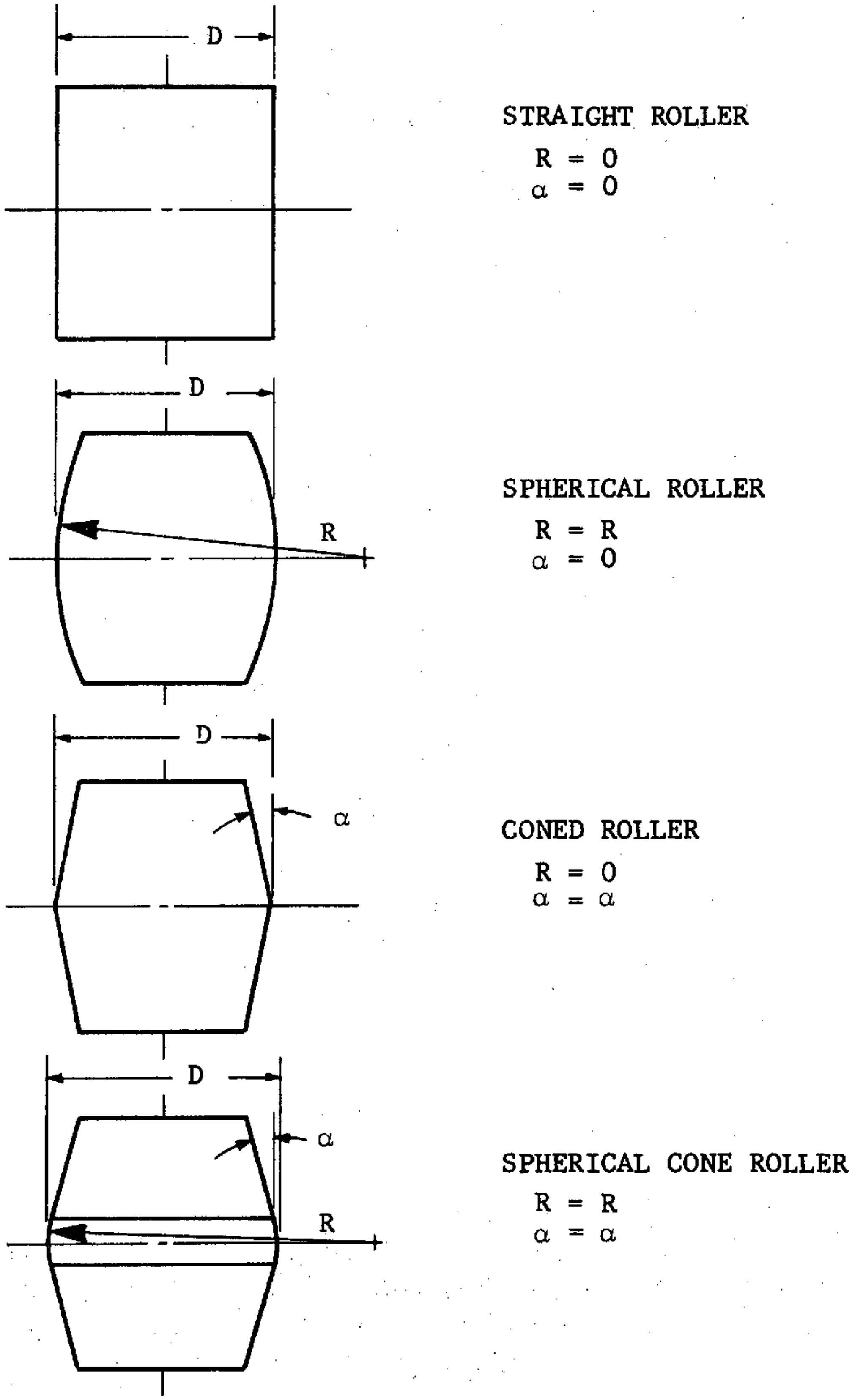


Figure C-2 ROLLER TYPES

Table C-1

INPUT DATA SPECIFICATION

Card Number	Variable Name	Description	Field Width	Format	Units
1	I	= 1, oxide out	1	I1	---
		= 0, oxide in	1	I1	---
	D	Roller diameter	2-10	F9.0	in.
	TT	Tape tension	11-20	F10.0	oz
	W	Tape width	21-30	F10.0	in.
	R	Spherical radius	31-40	F10.0	in.
	ALF	Cone angle	41-50	F10.0	deg
2	TO	Oxide thickness	1-10	F10.0	in.
	TM	Mylar thickness	11-20	F10.0	in.
	EO	Oxide elastic modulus	21-30	F10.0	psi
	EM	Mylar elastic modulus	31-40	F10.0	psi
	PO	Poisson's ratio, oxide	41-50	F10.0	---
	PM	Poisson's ratio, mylar	51-60	F10.0	---

```
      1 READ(5,2) I,D,TT,W,R,ALF
      2 FORMAT (I1,F9.0,5F10.0)
        READ (5,3) TO,TM,EO,EM,PO,PM
      3 FORMAT (6F10.0)
        ALP=0.0174533*ALF
        WRITE (6,9)
      9 FORMAT (1H1,10X, 54HPRINCIPAL STRESSES IN TAPE PASSING OVER A ROLL
       1ER              /////)
        IF(ALF)40,40,41
   40 IF(R)42,42,43
   41 IF(R)45,45,44
   42 WRITE(6,46)TT,W,D
        R= 10000.*(D+W)
        ALP=W/R
        GO TO 50
   43 WRITE(6,47)TT,W,D,R
        ALP=W/R
        D=D+2.*R*(1./COS(ALP)-1.)
        GO TO 50
   44 WRITE(6,48)TT,W,D,R,ALF
        GO TO 50
   45 WRITE(6,49)TT,W,D,ALF
   46 FORMAT(5X,45HSTRAIGHT ROLLER                                   ////
       15X,19HPHYSICAL PARAMATERS ///
        2         8X,30HTAPE TENSION                   ,F10.2,2X,3HOZ.,/
        3         8X,30HTAPE WIDTH                     ,F10.3,2X,3HIN.,/
        4         8X,30HROLLER DIAMETER                ,F10.3,2X,3HIN.,//  )
   47 FORMAT(5X,45HSPHERICALLY CROWNED ROLLER                        ////
       15X,19HPHYSICAL PARAMATERS ///
        2         8X,30HTAPE TENSION                   ,F10.2,2X,3HOZ.,/
        3         8X,30HTAPE WIDTH                     ,F10.3,2X,3HIN.,/
        4         8X,30HROLLER DIAMETER                ,F10.3,2X,3HIN.,/
        5         8X,30HCROWN RADIUS                   ,F10.2,2X,3HIN.,//  )
   48 FORMAT(5X,45HDOUBLE CONED ROLLER WITH RADIUS                   ////
       15X,19HPHYSICAL PARAMATERS ///
        2         8X,30HTAPE TENSION                   ,F10.2,2X,3HOZ.,/
        3         8X,30HTAPE WIDTH                     ,F10.3,2X,3HIN.,/
        4         8X,30HROLLER DIAMETER                ,F10.3,2X,3HIN.,/
        5         8X,30HCROWN RADIUS                   ,F10.2,2X,3HIN.,/
        6         8X,30HCONE ANGLE                     ,F10.2,2X,3HDEG//)
   49 FORMAT(5X,45HDOUBLE CONED ROLLER                               ////
       15X,19HPHYSICAL PARAMATERS ///
        2         8X,30HTAPE TENSION                   ,F10.2,2X,3HOZ.,/
        3         8X,30HTAPE WIDTH                     ,F10.3,2X,3HIN.,/
        4         8X,30HROLLER DIAMETER                ,F10.3,2X,3HIN.,/
        5         8X,30HCONE ANGLE                     ,F10.2,2X,3HDEG//)
   50 WRITE (6,11)
   11 FORMAT (5X,15HTAPE PROPERTIES //)
        WRITE (6,15)TO,TM,EO,EM,PO,PM
   15 FORMAT ( 8X,30HOXIDE THICKNESS                ,F10.5,2X,3HIN.,/
        1         8X,30HMYLAR THICKNESS                ,F10.5,2X,3HIN.,/
        2         8X,30HOXIDE ELASTIC MODULUS          ,F10.0,2X,3HPSI,/
        3         8X,30HMYLAR ELASTIC MODULUS          ,F10.0,2X,3HPSI,/
        4         8X,30HPOISSON'S RATIO (OXIDE)        ,F10.2,2X,3H   ,/
        5         8X,30HPOISSON'S RATIO (MYLAR)        ,F10.2,2X,3H   ,//)
```

Figure C-3

Program for Tape Stresses Over Rollers

Figure C-3 Continued

```
      IF(I) 4,4,5
    4 E1=EO
      E2=EM
      P1=PO
      P2=PM
      T1=TO
      T2=TM
      TW=TT/W
      GO TO 6
    5 E1=EM
      E2=EO
      P1=PM
      P2=PO
      T1=TM
      T2=TO
      TW=TT/W
    6 CONTINUE
      CW=0
      T1L=T1
      T2L=T2
      EL=E2*(1.-P1*P1)/(E1*(1.-P2*P2))
      TE=T1L*E1+T2L*E2
      Y=(T1L*T1L+EL*T2L*T2L+2.*EL*T1L*T2L)/(2.*(T1L+EL*T2L))
*COMMENT*  THE TEST FOR EQUALITY BETWEEN NON-INTEGERS MAY NOT BE MEANINGFUL.
      IF(R.EQ.0.)R=T1+T2-Y
      DD=D
      D=D-2.*R*(1./COS(ALP)-1.)
      SBA=(E1*Y/(1.-P1*P1))*(2./D+P1/R)
      SBB=(E1*(Y-T1L)/(1.-P1*P1))*(2./D+P1/R)
      SBC=(E2*(Y-T1L)/(1.-P2*P2))*(2./D+P2/R)
      SBD=(E2*(Y-T1L-T2L)/(1.-P2*P2))*(2./D+P2/R)
   32 CWS=2.*R*ALP
      IF(CW-CWS)52,52,53
   52 ABC=R/(.5*D-R*(1.-COS(.5*CW/R)))
      Q1=E1*(1.-COS(.5*CW/R))*ABC
      Q2=E2*(1.-COS(.5*CW/R))*ABC
      TR=(CW/R)*(CW/R)
      TR=TE*ABC*(CW*TR/12.)*(1.-(TR/40.)*(1.-TR/112.))
      GO TO 54
   53 ABC=D-2.*R*(1.-COS(ALP))-(CW-CWS)*ALP
      Q1=(CW-CWS)*ALP*E1/ABC
      Q2=(CW-CWS)*ALP*E2/ABC
      TR=Q1*T1L*(CW+CWS)/2.+Q2*T2L*(CW+CWS)/2.
      ABC=R/(.5*D-R*(1.-COS(.5*CWS/R)))
      Q1=Q1+E1*(1.-COS(.5*CWS/R))*ABC
      Q2=Q2+E2*(1.-COS(.5*CWS/R))*ABC
      TR=TR+(T1L*E1+T2L*E2)*2.*(R*SIN(.5*CWS/R)-.5*CWS*COS(.5*CWS/R))*ABC
     1C
   54 TWL = (TT/15.-TR)/CW
      IF (TWL) 30,31,31
   30 CW=0.999*CW
```

Figure C-3 Continued

```
      GO TO 32
   31 S1=TWL*E1/TE
      S2=TWL*E2/TE
      SLA=SBA+Q1+S1
      SLB=SBB+Q1+S1
      SLC=SBC+Q2+S2
      SLD=SBD+Q2+S2
      SWA=(E1*Y/(1.-P1*P1))*(1./R+2.*P1/D)
      SWB=(E1*(Y-T1L)/(1.-P1*P1))*(1./R+2.*P1/D)
      SWC=(E2*(Y-T1L)/(1.-P2*P2))*(1./R+2.*P2/D)
      SWD=(E2*(Y-T1L-T2L)/(1.-P2*P2))*(1./R+2.*P2/D)
      STA=0.0
      STB=0.0
      STC=0.0
      STD=0.0
      T=TW*W
      TR=TR*16.
      IF (I) 7,7,8
    7 SOSL = SLA
      SOST = STA
      SOSW = SWA
      SOCL = SLB
      SOCT = STB
      SOCW = SWB
      SMSL = SLD
      SMST = STD
      SMSW = SWD
      SMCL = SLC
      SMCT = STC
      SMCW = SWC
      GO TO 20
    8 SOSL = SLD
      SOST = STD
      SOSW = SWD
      SOCL = SLC
      SOCT = STC
      SOCW = SWC
      SMSL = SLA
      SMST = STA
      SMSW = SWA
      SMCL = SLB
      SMCT = STB
      SMCW = SWB
```

Figure C-3 Continued

```
      20 CONTINUE
         WRITE(6,51) CW
      51 FORMAT(/5X33HCONTACT WIDTH                             ,F10.4,2X3HIN.,////)
          IF (I) 25,25,26
      25 WRITE (6,12)
      12 FORMAT(5X,43HOXIDE STRESSES,PSI (OXIDE AWAY FROM ROLLER)//)
         GO TO 23
      26 WRITE (6,22)
      22 FORMAT (5X,41HOXIDE STRESSES,PSI (OXIDE AGAINST ROLLER)//)
      23 CONTINUE
         WRITE (6,16) SOSL,SOST,SOSW,SOCL,SOCT,SOCW
      16OFORMAT (  8X,30HSURFACE,LENGTH DIRECTION         ,F10.0,2X,3HPSI,/
        1          8X,30HSURFACE,THICKNESS DIRECTION      ,F10.0,2X,3HPSI,/
        2          8X,30HSURFACE,WIDTH DIRECTION          ,F10.0,2X,3HPSI,/
        3          8X,30HCENTER,LENGTH DIRECTION          ,F10.0,2X,3HPSI,/
        4          8X,30HCENTER,THICKNESS DIRECTION       ,F10.0,2X,3HPSI,/
        5          8X,30HCENTER,WIDTH DIRECTION           ,F10.0,2X,3HPSI,//)
         WRITE (6,13)
      13 FORMAT (5X,18HMYLAR STRESSES,PSI //)
         WRITE (6,17) SMSL,SMST,SMSW,SMCL,SMCT,SMCW
      17OFORMAT (  8X,30HSURFACE,LENGTH DIRECTION         ,F10.0,2X,3HPSI,/
        1          8X,30HSURFACE,THICKNESS DIRECTION      ,F10.0,2X,3HPSI,/
        2          8X,30HSURFACE,WIDTH DIRECTION          ,F10.0,2X,3HPSI,/
        3          8X,30HCENTER,LENGTH DIRECTION          ,F10.0,2X,3HPSI,/
        4          8X,30HCENTER,THICKNESS DIRECTION       ,F10.0,2X,3HPSI,/
        5          8X,30HCENTER,WIDTH DIRECTION           ,F10.0,2X,3HPSI,//)
         GO TO 1
         END

 END OF UCC 1108 FORTRAN V COMPILATION.
   1    *COMMENT*     0 *DIAGNOSTIC*
   0      *ERROR*     0 *FATAL ERROR*
```

PRINCIPAL STRESSES IN TAPE PASSING OVER A ROLLER

DOUBLE CONED ROLLER WITH RADIUS

PHYSICAL PARAMATERS

TAPE TENSION	24.00	OZ.
TAPE WIDTH	.375	IN.
ROLLER DIAMETER	1.000	IN.
CROWN RADIUS	2.00	IN.
CONE ANGLE	2.00	DEG

TAPE PROPERTIES

OXIDE THICKNESS	.00046	IN.
MYLAR THICKNESS	.00046	IN.
OXIDE ELASTIC MODULUS	550000.	PSI
MYLAR ELASTIC MODULUS	550000.	PSI
POISSON'S RATIO (OXIDE)	.45	
POISSON'S RATIO (MYLAR)	.45	

CONTACT WIDTH	.3750	IN.

OXIDE STRESSES,PSI (OXIDE AWAY FROM ROLLER)

SURFACE,LENGTH DIRECTION	7505.	PSI
SURFACE,THICKNESS DIRECTION	0.	PSI
SURFACE,WIDTH DIRECTION	445.	PSI
CENTER,LENGTH DIRECTION	6797.	PSI
CENTER,THICKNESS DIRECTION	0.	PSI
CENTER,WIDTH DIRECTION	-0.	PSI

MYLAR STRESSES,PSI

SURFACE,LENGTH DIRECTION	6090.	PSI
SURFACE,THICKNESS DIRECTION	0.	PSI
SURFACE,WIDTH DIRECTION	-445.	PSI
CENTER,LENGTH DIRECTION	6797.	PSI
CENTER,THICKNESS DIRECTION	0.	PSI
CENTER,WIDTH DIRECTION	-0.	PSI

Fig. C-4. Input/Output Data of Tape Stress Program

Following this listing are the maximum values of the orthogonal stress components at the inner and outer surfaces of the two layers. The maximum tensile stress values usually occur in the tape length direction. Compressive stresses are shown as negative values.

APPENDIX D

TAPE PACK STRESS PROGRAM

APPENDIX D

TAPE PACK STRESS PROGRAM

INTRODUCTION

The usual method of handling and storing magnetic tape is to wind the tape on a suitable hub. Furthermore, tape packs are commonly wound under constant tension conditions, although constant torque winding, i.e., decreasing the tension in inverse proportion to the instantaneous pack radius, is also used.

A common and continuing problem with such tape packs is the tendency of spoking or buckling to occur within the pack. The reduction or the elimination of this buckling behavior is extremely important in audio and video recorded tape since it results in information loss through tape damage.

Tape Pack Stress Distributions

It is generally conceded that buckling within a tape pack can only occur within a region of compressive longitudinal tape stress. Since tape is initially wound in the positive or tensile stress condition, the tensile stress decay and final stress distribution within the pack must be determined so the presence of compressive stress regions can be noted.

IITRI has developed a digital computer program which determines the state of stress within a tape pack. This program, based upon the elastic properties of tape and hub materials, accounts for the effects of:

- Number of tape layers, or tape length
- Winding tape tension magnitude
- Hub stiffness
- Hub radius
- Winding tape tension profile

The tape pack stress profile is calculated using an iterative procedure based upon the thick-walled pressure vessel equations. A typical stress distribution, for a constant tension wind, is shown in Figure D-1. As tape layers are added to the pack, the inner layers are compressed and their original tensile stresses are reduced.

The effect of additional tape layers, wound at constant tension (stress), on the stress distribution within the pack is shown in Figure D-2. A sufficient number of layers can cause the inner layers to develop negative or compressive stresses which leads to possible buckling.

The effect, on the stress distribution, of winding identical packs at different constant tension levels is shown in Figure D-3.

The stress distribution within the pack can be radically changed by varying the winding tension as the pack is wound. Three cases other than constant tension, are shown in Figure D-4. Increasing winding tension rapidly compresses the inner layers and is the least desirable technique. Maintaining a constant winding torque requires a decrease in tension and is easily implemented. Decreasing the tension from an initial value down to zero will result in a near zero stress of the outer layers.

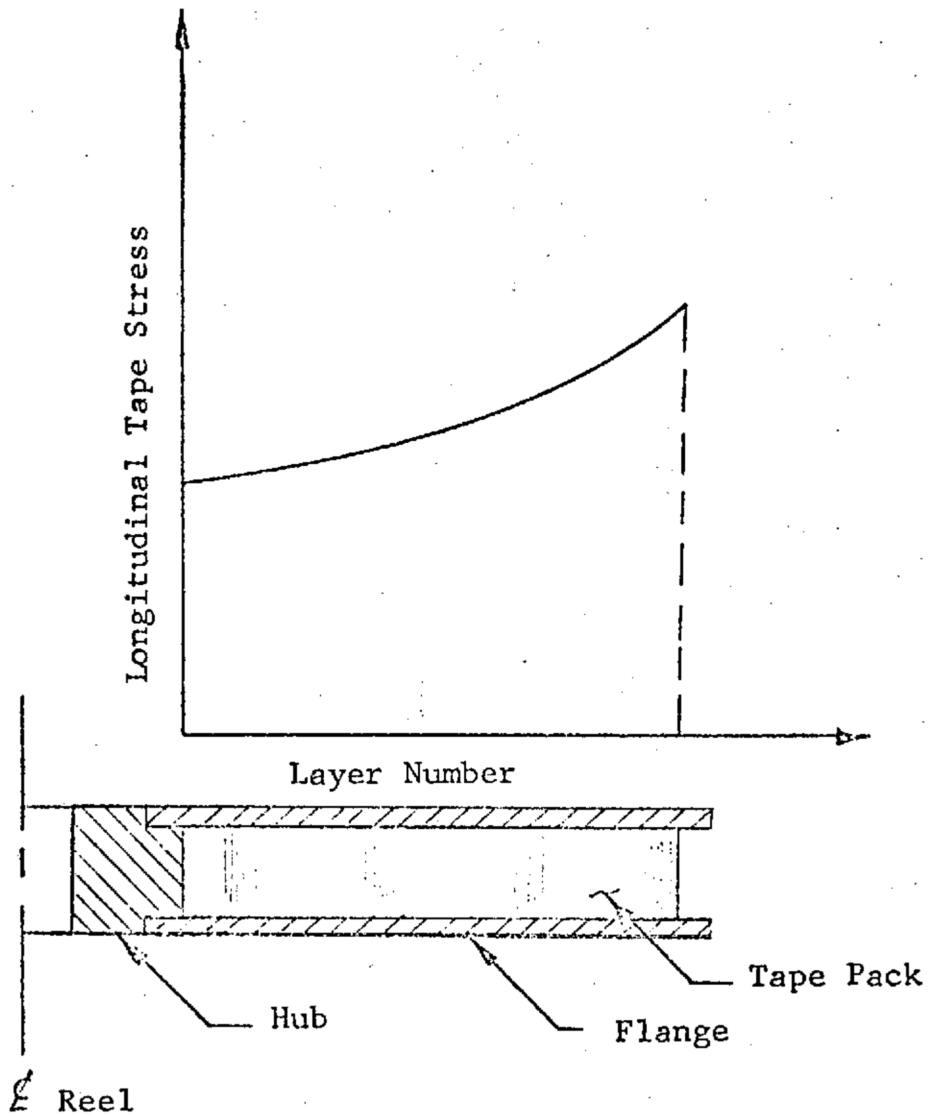


Fig. D-1 TYPICAL TAPE STRESS PROFILE

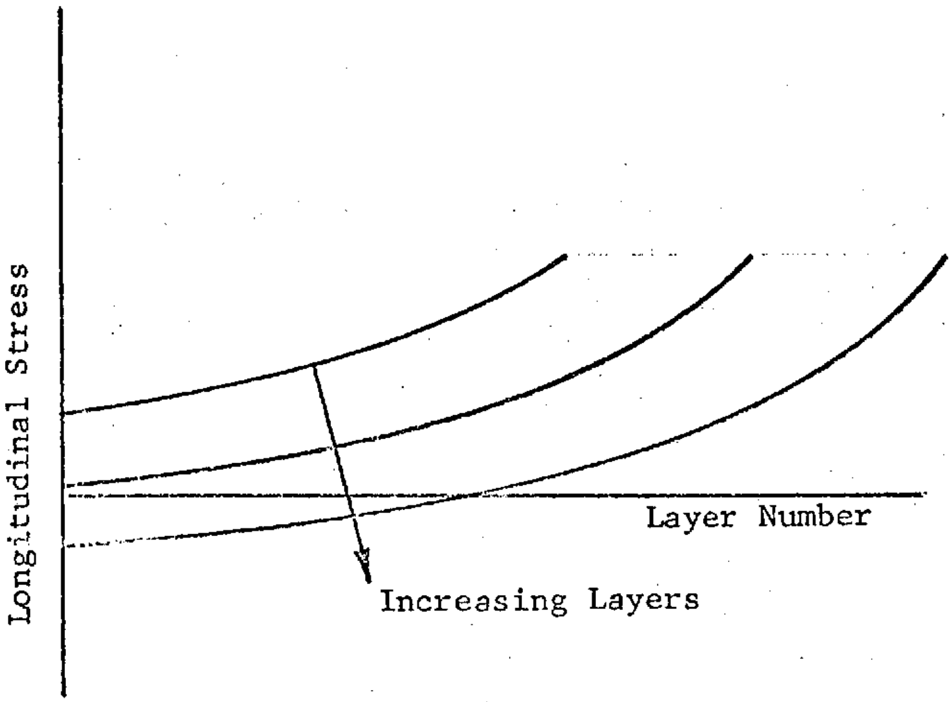


Fig. D-2 EFFECT OF INCREASED TAPE LAYERS

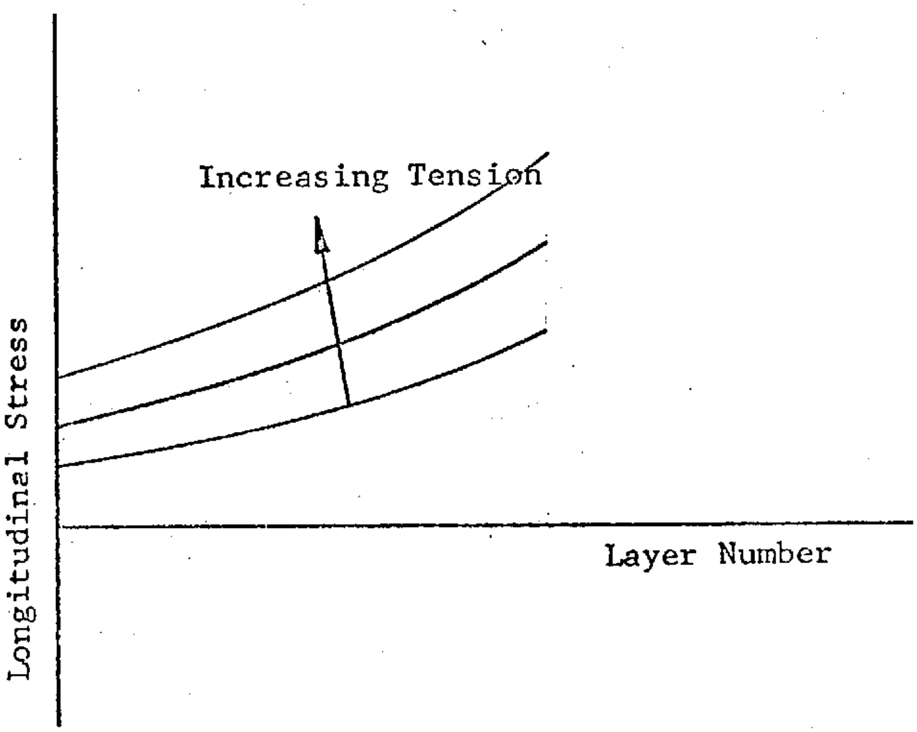


Fig. D-3 EFFECT OF HIGHER TAPE TENSIONS

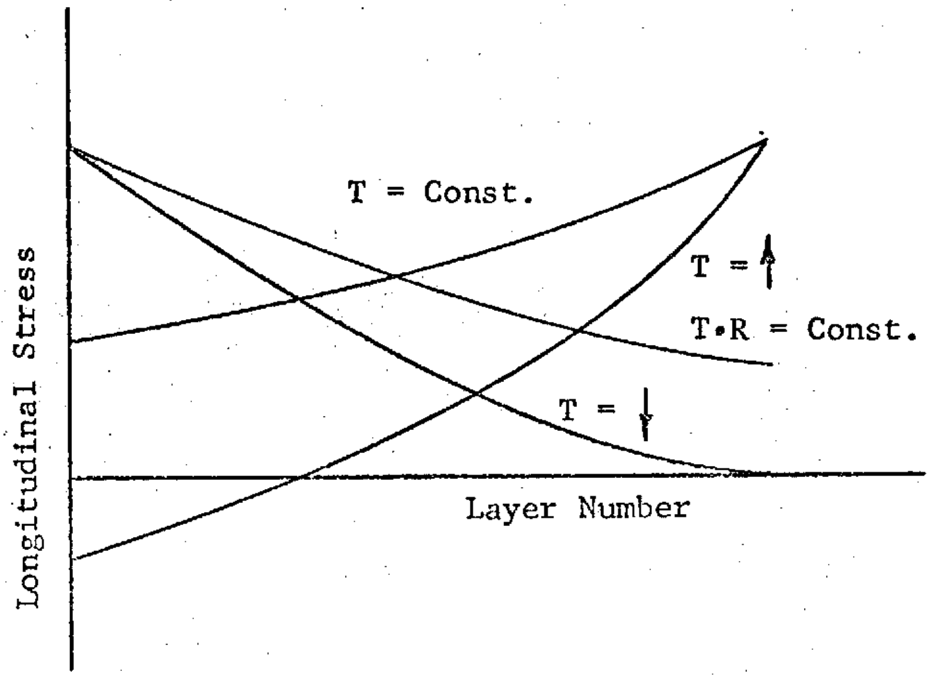


Fig. D-4 EFFECT OF TENSION PROFILE

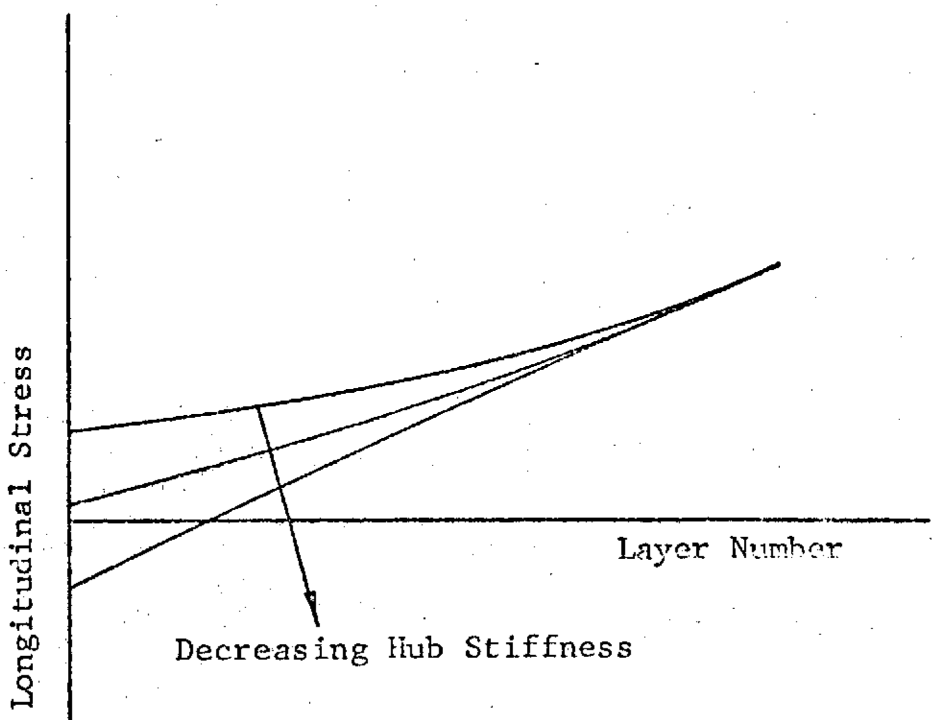


Fig. D-5 EFFECT OF HUB STIFFNESS

Two factors frequently ignored in the design of a tape pack are the hub stiffness and the hub radius. An insufficiently stiff hub allows the pack to compress, and can result in compressive stress regions within the pack as shown in Figure D-5. Increasing the hub radius has the desirable effect of alleviating inner layer compression as shown in Figure D-6.

The above mentioned stress distributions are presented here in a qualitative manner in order to show tape pack behavior. Absolute values of stress can be calculated with the IITRI computer program for all of the above cases.

Computer Program

The tape pack computer program developed is shown in Figure D-7. This program is written in the Fortran IV language.

The input data specifications are given in Table D-1, and a typical input/output data listing is shown in Figure D-8.

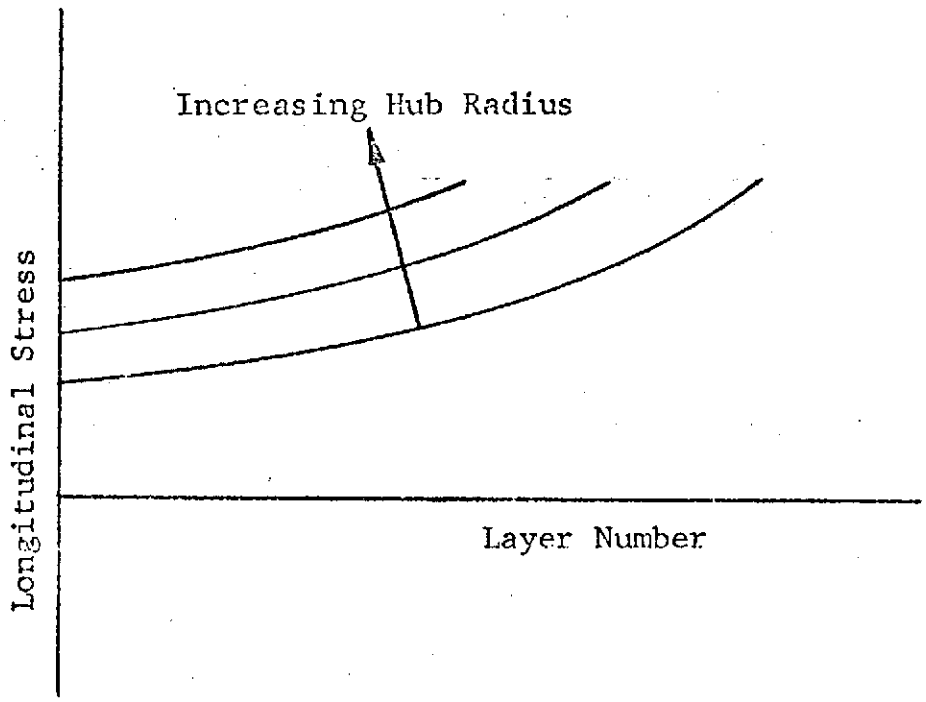


Fig. D-6 EFFECT OF HUB RADIUS

```
      DIMENSION S(5000)
    1 READ (5,2) TR,WR,ER,RR,TT,WT,ET,PT,T,IT,II,RP
    2 FORMAT (2F5.0,F10.0,1F5.0,F6.0,F4.0,F10.0,2F5.0,2I5,F5.0)
      WRITE (6,3) TR,WR,ER,RR,RP,TT,WT,ET,PT,T
    3 FORMAT (19H1TAPE PACK STRESSES///9X2HTR,10X2HWR,7X2HER,13X2HRR,10
     1X2HRP/2F12.4,F12.0,2F12.4//9X2HTT,10X2HWT,8X2HET,12X2HPT,13X1HT
     2/F12.5,F12.4,F12.0,2F12.4/)
      T=T/16.0
      I=1
      IQ=II+1
      R=RR
      A=RR
      B=RR
      DO 4 J=1,5000
    4 S(J)=T/(WT*TT)
      TL=.52359878*B
      WRITE (6,5) I,R,S(1)
    5 FORMAT (/6H WRAPS,4X6HRADIUS,6X6HSTRESS/I6,F10.3,F12.0//6H WRAPS,
     14X6HRADIUS,6X6HSTRESS)
    6 I=I+1
      B=B+TT
      TL=TL+.52359878*B
      IF (I-IT) 7,1,1
    7 P=T/(WT*B)
      PR=(P/ET)*(2.*B*B/(B*B-A*A))/((WT/(WR*ER))*((2.*A*(A-TR)+TR*TR)/(T
     1R*(2.*A-TR))+RP)+(B*B+A*A)/(ET*(B*B-A*A))+PT/ET)
      J=1
    8 AJ=J
      R=RR+AJ*TT
      DSJ=(PR*A*A/(R*R))*(B*B+R*R)/(B*B-A*A)-(P*B*B/(R*R))*(A*A+R*R)/(B*
     1B-A*A)
      S(J)=S(J)+DSJ
      IF (I-IQ) 11,9,9
    9 WRITE (6,10) J,R,S(J)
   10 FORMAT (I6,F10.3,F12.0)
   11 J=J+II
      IF (J-I) 8,12,12
   12 IF (I-IQ) 6,13,13
   13 IQ=IQ+II
      WRITE (6,14) I,TL
   14 FORMAT (//1H ,I6,10H WRAPS OR ,F5.0,49H FEET OF TAPE WERE USED FOR
     1 THE PRECEDING RESULTS//6H WRAPS,4X6HRADIUS,6X6HSTRESS)
      GO TO 6
      END

END OF UCC 1108 FORTRAN V COMPILATION.
  0    *COMMENT*     0 *DIAGNOSTIC*
  0      *ERROR*     0 *FATAL ERROR*
```

Figure D-7
Tape Pack Stress Program

Table D-1

INPUT DATA SPECIFICATION

Card Number	Variable Name	Description	Field Width	Format	Units
1	TR	Radial reel thickness	1-5	F5.0	in.
	WR	Width of reel	6-10	F5.0	in.
	ER	Reel elastic modulus	11-20	F10.0	psi
	RR	Hub radius	21-25	F5.0	in.
	TT	Tape thickness	26-31	F6.0	in.
	WT	Tape width	32-35	F4.0	in.
	ET	Tape elastic modulus	36-40	F10.0	psi
	PT	Poisson's ratio for tape	41-45	F5.0	---
	T	Tape tension	46-50	F5.0	oz
	IT	Total number of wraps	51-55	I5	---
	II	Print interval	56-60	I5	---
	RP	Poisson's ratio for reel	61-65	F5.0	---

TAPE PACK STRESSES

TR	WR	ER	RR	RP
.3750	.5400	16400000.	.8125	.3200
TT	WT	ET	PT	T
.00112	.5000	650000.	.4500	0.0000

WRAPS	RADIUS	STRESS
1	.814	273.
101	.926	280.
201	1.038	309.
301	1.150	350.
401	1.262	397.
501	1.374	446.
601	1.486	496.
701	1.598	545.
801	1.710	594.
901	1.822	641.
1001	1.934	687.
1101	2.046	731.
1201	2.158	774.
1301	2.270	815.
1401	2.382	855.

1501 WRAPS OR 1299. FEET OF TAPE WERE USED FOR THE PRECEDING RESULTS

Figure D-8

Input/Output Data for Tape Pack Stress Program

APPENDIX E

RESPONSE PROGRAM

APPENDIX E

RESPONSE PROGRAM

INTRODUCTION

Natural frequencies and vibration response of tape transport mechanical components (idler, capstan, reel, and tape) are calculated on this tape transport dynamic simulation model (TTDSM). The model, as programmed on the digital computer, is problem-oriented. Information is entered into the computer on the basis of stacking data cards which contain the information for individual components (idler, length of tape, reel, etc.).

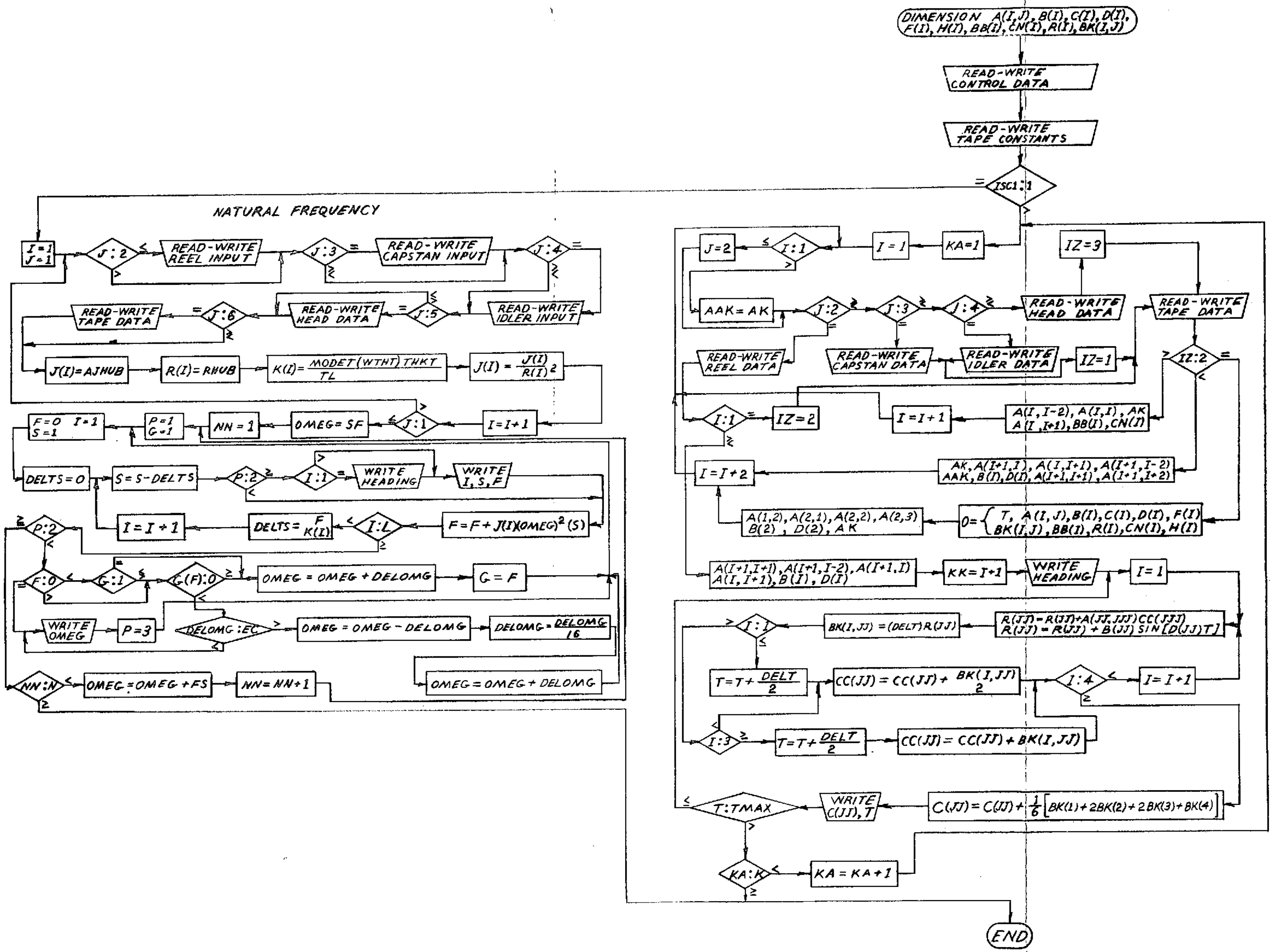
Natural frequency calculations are performed using the Holzer Method of calculation, and the steady state vibration response is obtained through the use of a standard simultaneous equation solver.

Computer Program

The flow diagram for TTDSM is shown in Figure E-1. The computer program follows on Figure E-2. The simulation of a specific model transport is attained by proper sequencing of the data cards.

Computer Program Documentation

Figure E-3 shows the physical arrangement of the computer cards for the tape transport dynamic simulation model. Specific description of the individual cards follow. This description includes the computer code name, the element description, its field on the data card, format and units.



FOLDOUT FRAME

FIGURE E-1 TAPE TRANSPORT DYNAMIC SIMULATION MODEL COMPUTER FLOW DIAGRAM

FOLDOUT FRAME

```
      DIMENSION A(25,25),B(25),C(25),D(25),TL(25)      ,BB(25),CN(25),R(2
     15),BK(25,25),AJ(25),AK(25),F(25),CC(25),         X(25),IR(25),JC(25
     2),XD(25,25)
      DIMENSION BBB(25,1)
      REAL MODET
      KA = 1
      DO 4 I=1,25,1
      DO 4 JJ=1,25,1
    4 XD(I,JJ) = 0.0
    5 DO 761 I=1,25,1
      DO 760 JI=1,25,1
      A(I,JI)= 0.0
  760 BK(I,JI)= 0.0
      B(I) = 0.0
      BB(I) = 0.0
      C(I)= 0.0
      CC(I) = 0.0
      D(I) = 0.0
      IR(I) = 0
      JC(I) = 0
      F(I) = 0.0
      CN(I) = 0.0
      R(I) = 0.0
      TL(I) = 0.0
      AJ(I) = 0.0
        X(I) = 0.0
      TTL=0.0
  761 AK(I) = 0.0
      READ (5,10) DELT,TMAX,AMT,EC,SF,N,K,ISC1,ISC2,FS,FL
   10 FORMAT ( 5E10.5, 4I3, E10.5,E8.3)
      READ (5,20) DENST,MODET,THKT,WTHT,V
   20 FORMAT ( 5E10.5 )
      WRITE (6,30) DELT,TMAX,AMT,EC,SF,N,K,ISC1,ISC2,FS,FL
   30 FORMAT (  19H1CONTROL INPUT DATA//7H DELTA=E10.5,5X6HT MAX=E10.5,5
     1X9HAMT.TAPE=E10.5,5X12HERROR CRIT.=E10.5,5X8HST.FREQ=E10.5/9H NO.F
     2REQ=I3,10X8HNO.SETS=I3,10X4HSC1=I3,17X4HSC2=I3,24X10HFREQ.INT.=E10
     3.5/15H MAX.FREQUENCY=E8.3/)
      WRITE (6,40) DENST,MODET,THKT,WTHT,V
   40 FORMAT (  16H TAPE INPUT DATA/ 9H DENSITY=E10.5,5X9HMOD.ELST=E10.5
     1,5X9HTHK.TAPE=E10.5,5X9HWTH.TAPE=E10.5,5X9HTAPE VEL=E10.5/)
      WRITE (6,50)
   50 FORMAT (  26H TAPE TRANSPORT INPUT DATA /)
```

Figure E-2

Computer Program for TTDSM

```
      IF ( ISC1 - 2 )  55, 486, 1486
C   NATURAL FREQUENCY
   55 I = 1
      J = 1
   60 JCC = 1
      IF ( J - 2 ) 70, 70, 100
   70 READ (5,80) J,AJHUB,RHUB,FDRAG,TS,TC,AKD,RA,VA,M,NA
   80 FORMAT (I1,8E9.4,I1,I3)
      WRITE (6,90) J,AJHUB,RHUB,FDRAG,TS,TC,AKD,RA,VA,M,NA
   90 FORMAT(11H REEL,CODE=I1,2X10HINERT.HUB=E9.4,2X6HR.HUB=E9.4,2X10HDR
     1AG COEF=E9.4,2X13HPERT.TORQ(S)=E9.4,2X13HPERT.TORQ(C)=E9.4/6X5HFLU
     2X=E9.4,2X7HRESIST=E9.4,2X6HVOLTS=E9.4,2X6HPT.CD=I1,2X3HNA=I3//)
  100 IF ( J - 3) 140, 110, 140
  110 READ (5,120) J,AJHUB,RHUB,FDRAG,TS,TC,AKD,RA,VA,M,NA
  120 FORMAT (I1,8E9.4,I1,I3)
      WRITE (6,130) J,AJHUB,RHUB,FDRAG,TS,TC,AKD,RA,VA,M,NA
  130 FORMAT  (14H CAPSTAN,CODE=I1,2X10HINERT.HUB=E9.4,2X6HR.HUB=E9.4,2X
     110HDRAG COEF=E9.4,2X13HPERT.TORQ(S)=E9.4,2X13HPERT.TORQ(C)=E9.4/6X
     25HFLUX=E9.4,2X7HRESIST=E9.4,2X6HVOLTS=E9.4,2X6HPT.CD=I1,2X3HNA=I3/
     3/)
      IF ( J - 7 ) 140, 71, 140
   71 READ (5,72) J,BJHUB,GR
   72 FORMAT ( I1,2E9.4 )
      WRITE (6,73) J,BJHUB,GR
   73 FORMAT ( 22H CAPSTAN REDUCER,CODE=I1,10H  INERTIA=E9.4,13H   GEAR R
     1ATIO=E9.4//)
  140 IF ( J - 4) 180, 150, 180
  150 READ (5,160) J,AJHUB ,RHUB,FDRAG,TS,TC,AKD,RA,VA,M,NA
  160 FORMAT ( I1,8E9.4,I1,I3)
      WRITE (6,170) J,AJHUB,RHUB,FDRAG,TS,TC,M,NA
  170 FORMAT (12H IDLER,CODE=I1,2X10HINERT.HUB=E9.4,2X6HR.HUB=E9.4,2X10H
     1DRAG COEF=E9.4,2X13HPERT.TORQ(S)=E9.4,2X13HPERT.TORQ(C)=E9.4/2X6HP
     2T.CD=I1,2X3HNA=I3//)
  180 IF ( J - 5 ) 220, 190, 220
  190 READ (5,200) J,F0,F1,CNN,M
  200 FORMAT ( I1,3E9.4,I1 )
      WRITE (6,210) J,F0,F1,CNN,M
  210 FORMAT (11H HEAD,CODE=I1,2X11HSTAT.FRICT=E9.4,2X10HDYN.FRICT=E9.4,
     12X14HDYN.FRICT.(N)=E9.4,2X6HPT.CD=I1//)
      JCC = 4
      BA = TL(I-1)
  220 IF ( J - 6 ) 260, 230, 260
  230 READ (5,240) J,TLL,M
  240 FORMAT ( I1,E9.4,I1 )
      WRITE (6,250) J,TLL,M
  250 FORMAT (11H TAPE,CODE=I1,2X10HTAPE LGTH=E9.4,2X6HPT.CD=I1//)
      TL(I) = TLL
      IF (JCC - 4 ) 260, 255, 260
  255 TL(I-1)=TL(I)+BA
      AK(I-1) = ( MODET*THKT*WTHT ) / TL(I-1)
      GO TO 60
  260 AJ(I) = AJHUB + ( BJHUB*(GR**2.0))
      BJHUB = 0.0
      GR = 0.0
      R(I) = RHUB
      IF ( J - 1 ) 262,262, 261
  261 AK(I) = ( MODET*THKT*WTHT ) / TL(I)
```

Figure E-2 Continued

```
      262 AJ(I) = AJ(I) / ( R(I)**2.0)
          L = I
          I = I + 1
          IF ( J - 1 ) 270, 270, 60
      270 OMEG = SF
          NN = 1
      280 G = 1.0
          DELOMG = DELT
          IP = 1
      290 FA= 0.0
          S = 1.0
          DELTS = 0.0
          I = 1
      300 S = S - DELTS
          IF ( IP - 2 ) 360, 310, 310
      310 IF ( I  - 1 ) 340, 320, 340
      320 WRITE (6,330)
      330 FORMAT ( 30H NATURAL FREQUENCY CALCULATION// 9H  STATION,5X10HTHET
         1A(RAD),5X13HTORQUE(IN-LB)//)
      340 THE = S / R(I)
          WRITE (6,350) I,THE,FA
      350 FORMAT ( 7H        I2,5XE10.4,5XE10.4 )
      360 FA= FA+ AJ(I)*(OMEG**2.0)*S
          IF ( I - L ) 370, 380, 380
      370 DELTS = FA/ AK(I)
          I = I + 1
          GO TO 300
      380 IF ( IP - 2 ) 390, 470, 470
      390 IF ( FA-0.0) 400, 430, 410
      400 IF ( G - 1.0 ) 410, 420, 410
      410 AA = G * FA
          IF ( AA -0.0) 450, 420, 420
      420 OMEG = OMEG + DELOMG
          G = FA
          GO TO 290
      430 AOMEG = OMEG / 6.28318
          WRITE (6,440) NN,AOMEG
      440 FORMAT ( 22H1NATURAL FREQUENCY NO.I3,2H =E10.5,3H HZ//)
          IP = 3
          GO TO 290
      450 IF ( DELOMG - EC ) 430, 460, 460
      460 OMEG = OMEG - DELOMG
          DELOMG = DELOMG / 16.0
          OMEG = OMEG + DELOMG
          GO TO 290
      470 IF ( NN - N ) 4800,481, 481
     4800 IF ( OMEG - FL ) 480, 481, 481
      480 OMEG = OMEG + FS
          NN = NN + 1
          GO TO 280
      481 IF ( KA - K ) 482, 10000, 10000
      482 KA = KA + 1
          GO TO 5
C    TIME TRANSIENT RESPONSE
      486 I = 1
      490 IF ( I - 1 ) 495, 495, 500
      495 J = 2
```

```
      GO TO 505
  500 AAK = AK(I-2)
  505 IF ( J - 2 ) 540, 510, 540
  510 READ (5,520)J,AJHUB,RHUB,FDRAG,TS,TC,AKD,RA,VA,M,NA
  520 FORMAT (I1,8E9.4,I1,I3)
      WRITE (6,530)J,AJHUB,RHUB,FDRAG,TS,TC,AKD,RA,VA,M,NA
  530 FORMAT(11H REEL,CODE=I1,2X10HINERT.HUB=E9.4,2X6HR.HUB=E9.4,2X10HDR
     1AG COEF=E9.4,2X13HPERT.TORQ(S)=E9.4,2X13HPERT.TORQ(C)=E9.4/6X5HFLU
     2X=E9.4,2X7HRESIST=E9.4,2X6HVOLTS=E9.4,2X6HPT.CD=I1,2X3HNA=I3//)
      IF (I - 1 ) 780, 660, 780
  540 IF ( J - 3) 580, 550, 580
  550 READ (5,560)J,AJHUB,RHUB,FDRAG,TS,TC,AKD,RA,VA,M,NA
  560 FORMAT (I1,8E9.4,I1,I3)
      WRITE (6,570)J,AJHUB,RHUB,FDRAG,TS,TC,AKD,RA,VA,M,NA
  570 FORMAT  (14H CAPSTAN,CODE=I1,2X10HINERT.HUB=E9.4,2X6HR.HUB=E9.4,2X
     110HDRAG COEF=E9.4,2X13HPERT.TORQ(S)=E9.4,2X13HPERT.TORQ(C)=E9.4/6X
     25HFLUX=E9.4,2X7HRESIST=E9.4,2X6HVOLTS=E9.4,2X6HPT.CD=I1,2X3HNA=I3/
     3/)
      GO TO 670
  580 IF ( J - 4 ) 630, 590, 630
  590 READ (5,600)J,AJHUB,RHUB,FDRAG,TS,TC,AKD,RA,VA,M,NA
  600 FORMAT ( I1,8E9.4,I1,I3)
      WRITE (6,610)J,AJHUB,RHUB,FDRAG,TS,TC,M,NA
  610 FORMAT (12H IDLER,CODE=I1,2X10HINERT.HUB=E9.4,2X6HR.HUB=E9.4,2X10H
     1DRAG COEF=E9.4,2X13HPERT.TORQ(S)=E9.4,2X13HPERT.TORQ(C)=E9.4/5X6HP
     2T.CD=I1,2X3HNA=I3//)
      GO TO 670
  630 READ (5,640) J,F0,F1,CNN,M
  640 FORMAT ( I1,3E9.4,I1)
      WRITE (6,650) J,F0,F1,CNN,M
  650 FORMAT (11H HEAD,CODE=I1,2X11HSTAT.FRICT=E9.4,2X10HDYN.FRICT=E9.4,
     12X14HDYN.FRICT.(N)=E9.4,2X6HPT.CD=I1//)
      IZ = 3
      GO TO 700
  660 IZ = 2
      GO TO 700
  670 IZ = 1
  700 READ (5,710) J,TLL,M
  710 FORMAT ( I1,E9.4,I1 )
      WRITE (6,720) J,TLL,M
  720 FORMAT (11H TAPE,CODE=I1,2X10HTAPE LGTH=E9.4,2X6HPT.CD=I1//)
      TL(I) = TLL
      IF ( IZ - 2 ) 730, 750, 740
  730 AK(I)=((MODET * THKT* WTHT) / TL(I))
      A(I,I+1) = 1.0
      A(I+1,I-2) = (( AAK)*( RHUB**2.0)) / AJHUB
      A(I+1,I) = (-1.0)*(( RHUB**2.0)/ AJHUB)* ( AAK + AK(I))
      A(I+1,I+1) =((-1.0)/AJHUB) * ( FDRAG + ((AKD**2.0) /RA ))
      A(I+1,I+2) =  ((RHUB**2.0)/AJHUB )*AK(I)
      B(I) = (TS* RHUB)/ AJHUB
      D(I) = (NA* V ) /RHUB
      GO TO 770
  740 AK(I)=((MODET *THKT* WTHT) / TL(I))
      A(I,I-2) = AAK / F1
      A(I,I) =  (AK(I)-AAK ) / F1
      A(I,I+1) =  -AK(I) / F1
      BB(I) = -F0 / F1
```

```
      CN(I) = CNN
      AAK = AK(I)
      I = I + 1
      GO TO 505
  750 I = 1
      T = 0.0
      AK(I)=((MODET * THKT * WTHT) / TL(I))
      A(1,2) = 1.0
      A(2,1) =  (-1.0)*(( RHUB**2.0) / AJHUB)* AK(I)
      A(2,2) = (-1.0 / AJHUB)* ( FDRAG + (( AKD**2.0 ) / RA))
      A(2,3) = (-1.0)* A(2,1)
      B(2) = ( TS* RHUB) / AJHUB
      D(2) = ( NA* V ) / RHUB
  770 I = I +2
      GO TO 490
  780 A(I,I+1) = 1.0
      A(I+1,I-2)=  ( AAK* (RHUB**2.0)) / AJHUB
      A(I+1,I) = (-1.0)* ((RHUB**2.0) / AJHUB ) * AAK
      A(I+1,I+1) = ( -1.0/AJHUB) *  ( FDRAG + (( AKD**2.0) / RA ))
      B(I) = ( TS* RHUB) / AJHUB
      D(I) = ( NA * V ) / RHUB
      KK = I +1
      WRITE (6,785)
  785 FORMAT ( 23H1FORCED RESPONSE OUTPUT//)
  790 I = 1
  795 DO 810 JJ=1,KK,1
      IF ( BB(JJ) - 0.0 ) 796, 7988, 796
  796 IF ( R(JJ) - 0.0 ) 798, 7989, 7988
 7989 ABB = 0.0
      GO TO 799
  798 ABB = -1.0*BB(JJ)
      GO TO 799
 7988 ABB = BB(JJ)
  799 DO 800 JJJ=1,KK,1
  800 R(JJ) = R(JJ) + A(JJ,JJJ)*CC(JJJ)
      R(JJ) = R(JJ) + B(JJ)*( SIN( D(JJ)*T)) + ABB
  810 CONTINUE
      DO 820 JJ=1,KK,1
      BK(I,JJ) = DELT * R(JJ)
  820 CONTINUE
      IF ( I - 1 ) 830, 830, 860
  830 T = T + ( DELT / 2.0 )
  840 DO 850 JJ=1,KK,1
  850 CC(JJ) = CC(JJ) + ( BK(I,JJ) / 2.0 )
      GO TO 890
  860 IF ( I - 3 ) 840,870,900
  870 T = T + ( DELT / 2.0 )
      CC(JJ) = CC(JJ) + BK(I,JJ)
  890 I = I + 1
      GO TO 795
  900 DO 940 JJ=1,KK,1
      I = 1
  910 C(JJ) = C(JJ) + (1.0 /6.0)*(  BK(I,JJ) +(2.0*BK(I+1,JJ))+(2.0*BK(I
     1+2,JJ)) + BK(I+3,JJ))
      IF ( JJ- 1 ) 920, 920, 931
  920 WRITE (6,930) T,C(JJ)
  930 FORMAT ( 6H TIME=E10.4,5X9HRESPONSE=E10.4//)
```

```
      GO TO 940
  931 WRITE (6,932) JJ,C(JJ)
  932 FORMAT ( 4H JJ=I3,2X6HC(JJ)=E10.4)
  940 CONTINUE
      IF ( T - TMAX ) 790, 790, 1000
 1000 IF ( KA - K ) 1010, 10000, 10000
 1010 KA = KA + 1
      GO TO 5
C   STEADY STATE RESPONSE
 1486 I = 1
 1490 IF ( I - 1 ) 1495, 1495, 1500
 1495 J = 2
      GO TO 1505
 1500 AAK = AK(I-2)
      CCH = CH
 1505 IF ( J - 2 ) 1540, 1510, 1540
 1510 READ (5,1520)J,AJHUB,RHUB,FDRAG,TS,TC,AKD,RA,VA,M,NA
 1520 FORMAT (I1,8E9.4,I1,I3)
      WRITE (6,1530)J,AJHUB,RHUB,FDRAG,TS,TC,AKD,RA,VA,M,NA
 1530 FORMAT(11H REEL,CODE=I1,2X10HINERT.HUB=E9.4,2X6HR.HUB=E9.4,2X10HDR
     1AG COEF=E9.4,2X13HPERT.TORQ(S)=E9.4,2X13HPERT.TORQ(C)=E9.4/6X5HFLU
     2X=E9.4,2X7HRESIST=E9.4,2X6HVOLTS=E9.4,2X6HPT.CD=I1,2X3HNA=I3//)
      IF (I - 1 ) 1780, 1660, 1780
 1540 IF ( J - 3) 1580, 1550, 1580
 1550 READ (5,1560)J,AJHUB,RHUB,FDRAG,TS,TC,AKD,RA,VA,M,NA
 1560 FORMAT (I1,8E9.4,I1,I3)
      WRITE (6,1570)J,AJHUB,RHUB,FDRAG,TS,TC,AKD,RA,VA,M,NA
 1570 FORMAT  (14H CAPSTAN,CODE=I1,2X10HINERT.HUB=E9.4,2X6HR.HUB=E9.4,2X
     110HDRAG COEF=E9.4,2X13HPERT.TORQ(S)=E9.4,2X13HPERT.TORQ(C)=E9.4/6X
     25HFLUX=E9.4,2X7HRESIST=E9.4,2X6HVOLTS=E9.4,2X6HPT.CD=I1,2X3HNA=I3/
     3/)
      IF ( J - 7 ) 1670, 1571, 1670
 1571 READ (5,1572) J,BJHUB,GR,BFDRAG,BAKD,BRA
 1572 FORMAT ( I1,5E9.4 )
      WRITE (6,1573) J,BJHUB,GR,BFDRAG,BAKD,BRA
 1573 FORMAT ( 22H CAPSTAN REDUCER,CODE=I1,10H  INERTIA=E9.4,13H  GEAR R
     1ATIO=E9.4,12H  DRAG COEF=E9.4,7H  FLUX=E9.4,13H  RESISTANCE=E9.4//
     2)
      BSF = SF * GR
      GR = 0.0
      GO TO 1670
 1580 IF ( J - 4 ) 1630, 1590, 1630
 1590 READ (5,1600)J,AJHUB,RHUB,FDRAG,TS,TC,AKD,RA,VA,M,NA
 1600 FORMAT ( I1,8E9.4,I1,I3)
      WRITE (6,1610)J,AJHUB,RHUB,FDRAG,TS,TC,M,NA
 1610 FORMAT (12H IDLER,CODE=I1,2X10HINERT.HUB=E9.4,2X6HR.HUB=E9.4,2X10H
     1DRAG COEF=E9.4,2X13HPERT.TORQ(S)=E9.4,2X13HPERT.TORQ(C)=E9.4/5X6HP
     2T.CD=I1,2X3HNA=I3//)
      GO TO 1670
 1630 READ (5,1640)J,FO,F1,CNN,M
 1640 FORMAT ( I1,3E9.4,I1)
      WRITE (6,1650)J,FO,F1,CNN,M
 1650 FORMAT (11H HEAD,CODE=I1,2X11HSTAT.FRICT=E9.4,2X10HDYN.FRICT=E9.4,
     12X14HDYN.FRICT.(N)=E9.4,2X6HPT.CD=I1//)
      IZ = 3
      GO TO 1700
 1660 IZ = 2
```

```
      GO TO 1700
 1670 IZ = 1
 1700 READ (5,1710)J,TLL,M,CH
 1710 FORMAT ( I1,E9.4,I1,E9.4)
      WRITE (6,1720)J,TLL,M,CH
 1720 FORMAT (11H TAPE,CODE=I1,2X10HTAPE LGTH=E9.4,2X6HPT.CD=I1,2X11HHEA
     1D COEF.=E9.4//)
      IF ( J - 5 ) 1725, 1721, 1725
 1721 TTL = TLL
      GO TO 1630
 1725 TLL = TLL + TTL
      TTL = 0.0
      IF ( IZ - 2 ) 1730, 1750, 1730
 1750 AK(I) = (( MODET* THKT* WTHT) / TLL)
      A(1,1) = ( RHUB*AK(I))-((AJHUB* ( SF**2.0)) /RHUB)
      BETA = (( AKD**2.0) / RA)
      A(1,2) = ((-SF/RHUB) * ( FDRAG+BETA ))-( RHUB*CH* SF)
      A(1,3) = (-AK(I)* RHUB)
      A(2,1) = -A(1,2)
      A(2,2) = A(1,1)
      A(2,4) =  A(1,3)
      B(1) = TS
      B(2) = TC
      A(1,4) = ( RHUB*CH* SF)
      A(2,3) = -A(1,4)
      I = I + 2
      GO TO 1490
 1730 AK(I) = (( MODET*THKT* WTHT) / TLL)
      A(I,I) = RHUB*(AAK+AK(I))-(( AJHUB*(SF**2.0)) / RHUB)-((BJHUB*(BSF
     1**2.0))/RHUB)
      BJHUB = 0.0
      A(I+1,I+1) = A(I,I)
      A(I,I-2) = -RHUB*AAK
      A(I,I-1) = RHUB*CCH*SF
      BETA = (( AKD**2.0) / RA)
      BBETA = (( BAKD**2.0) / BRA)
      A(I,I+1)= (-1.0)*((SF/RHUB)*(FDRAG+BETA ) +(RHUB*(CH+CCH)*SF) +
     1(( BSF**2.0) / RHUB) * ( BFDRAG + BBETA))
      BSF = 0.0
      BAKD = 0.0
      BRA = 0.0
      BBETA = 0.0
      BFDRAG = 0.0
      A(I,I+2) = -RHUB*AK(I)
      A(I,I+3) = RHUB*CH*SF
      A(I+1,I) = -A(I,I+1)
      A(I+1,I-2) = -A(I,I-1)
      A(I+1,I-1) = A(I,I-2)
      A(I+1,I+2) = -A(I,I+3)
      A(I+1,I+3) = A(I,I+2)
      B(I) = TS
      B(I+1) = TC
      I = I + 2
      GO TO 1490
 1780 A(I,I-2) = -RHUB*AAK
      A(I,I-1) = RHUB*CCH*SF
      A(I,I) = (RHUB*AAK) - ((AJHUB* (SF**2.0)) / RHUB)
```

Figure E-2 Continued

```
          BETA = (( AKD**2.0) / RA)
          A(I,I+1) = (-1.0)*((( FDRAG + BETA) /RHUB) +CCH)*SF
          A(I+1,I-2) = -A(I,I-1)
          A(I+1,I-1) = A(I,I-2)
          A(I+1,I) = -A(I,I+1)
          A(I+1,I+1) = A(I,I)
          B(I) = TS
          B(I+1) = TC
          KK = I + 1
          NMAX = 25
          ESP1 = 1.0
          N=KK
          DO 1971 JJ = 1,KK
     1971 BBB(JJ,1) = B(JJ)
          CALL INVER(A,14,BBB,1,DET)
          DO 1972 JJ = 1,KK
     1972 X(JJ) =BBB(JJ,1)
          WRITE (6,1975) KA
     1975 FORMAT ( 8H1SET NO,I3,16H RESPONSE OUTPUT    //)
          DO 1810 JJ=1,KK,2
          ARES = ((  X(JJ)**2.0) + (  X(JJ+1)**2.0))**0.5
          PHA = ATAN(   X(JJ) /    X(JJ+1))
          WRITE (6,1800) JJ,X(JJ)
     1800 FORMAT ( 12H ELEMENT NO,I3,5X9HRESPONSE=E10.5,1X6HINCHES)
          JZ = JJ+1
          WRITE (6,1801) JZ,X(JZ),ARES,PHA
     1801 FORMAT ( 12H ELEMENT NO,I3,5X9HRESPONSE=E10.5,1X6HINCHES,5X19HRESP
         1ONSE AMPLITUDE=E10.5,1X6HINCHES,5X6HPHASE=F9.4,1X4HRAD./)
          XD(KA,JJ) = SF * ARES
     1810 CONTINUE
          IF ( KA - K ) 1820, 1830, 1830
     1820 KA = KA + 1
          GO TO 5
     1830 CONTINUE
          WRITE (6,1831)
     1831 FORMAT ( 29H1TOTAL FORCED RESPONSE OUTPUT //)
          DO 1860 JJ=1,KK,2
          DO 1850 KA=1,K,1
     1850 AVEL = AVEL + XD(KA,JJ)**2.0
          VEL = ( AVEL**0.5)
          JZ = JJ+1
          WRITE (6,1851) JJ,JZ,VEL
     1851 FORMAT (  9H ELEMENT(I2,1H-I2,1H),5X9HVELOCITY=E10.5,9H IN./SEC./)
          AVEL = 0.0
          VEL = 0.0
     1860 CONTINUE
    10000 CONTINUE
          END
```

END OF COMPILATION: NO DIAGNOSTICS.

```
      SUBROUTINE INVER(A,N,B,M,DET)
C ****** INVER INPUT (A,N,B,M,DET)
C         A(1,1)X + A(1,2)Y + A(1,3)Z = B(1,1) + B(1,2)
C         A(2,1)X + A(2,2)Y + A(2,3)Z = B(2,1) + B(2,2)
C         A(3,1)X + A(3,2)Y + A(3,3)Z = B(3,1) + B(3,2)
C         N = NUMBER OF EQUATIONS
C         M = NUMBER OF COLUMNS ON LEFT SIDE - B(I,M)
C         N AND M MUST BE DEFINED IN CALLING PROGRAM IE. CALL INVER(A,3,B,2,DET)
C         DET = VALUE OF DETERMINANT
C         SET DIMENSION LIMITS EQUAL TO N,M
C ****** INVER OUTPUT (B,DET)
C         X = B(1,1)
C         Y = B(2,1)
C ****** Z = B(3,1)
C **** T DOES NOT EQUAL TIME IN THIS ROUTINE
      DIMENSION A(N,N),B(N,M),IPVOT(14),INDEX(14,14),PIVOT(14)
      EQUIVALENCE (IROW,JROW),(ICOL,JCOL)
   57 DET=1.
      DO 17 J=1,N
   17 IPVOT(J)=0
      DO 135 I=1,N
      T=0.
      DO 9 J=1,N
      IF(IPVOT(J)-1) 13,9,13
   13 DO 23 K=1,N
      IF(IPVOT(K)-1) 43,23,81
   43 IF(ABS(T)-ABS(A(J,K))) 83,23,23
   83 IROW=J
      ICOL=K
```

Figure E-2 Continued

```
          T=A(J,K)
      23 CONTINUE
       9 CONTINUE
          IPVOT(ICOL)=IPVOT(ICOL)+1
          IF(IROW-ICOL) 73,109,73
      73 DET=-DET
          DO 12 L=1,N
          T=A(IROW,L)
          A(IROW,L)=A(ICOL,L)
      12 A(ICOL,L)=T
          IF(M) 109,109,33
      33 DO 2 L=1,M
          T=B(IROW,L)
          B(IROW,L)=B(ICOL,L)
       2 B(ICOL,L)=T
     109 INDEX(I,1)=IROW
          INDEX(I,2)=ICOL
          PIVOT(I)=A(ICOL,ICOL)
          DET=DET*PIVOT(I)
          A(ICOL,ICOL)=1.
          DO 205 L=1,N
     205 A(ICOL,L)=A(ICOL,L)/PIVOT(I)
          IF(M) 347,347,66
      66 DO 52 L=1,M
      52 B(ICOL,L)=B(ICOL,L)/PIVOT(I)
     347 DO 135 LI=1,N
           IF(LI-ICOL) 21,135,21
      21 T=A(LI,ICOL)
          A(LI,ICOL)=0.
          DO 89 L=1,N
      89 A(LI,L)=A(LI,L)-A(ICOL,L)*T
          IF(M) 135,135,18
      18 DO 68 L=1,M
      68 B(LI,L)=B(LI,L)-B(ICOL,L)*T
     135 CONTINUE
     222 DO 3 I=1,N
          L=N-I+1
          IF  (INDEX(L,1)-INDEX(L,2)) 19,3,19
      19 JROW=INDEX(L,1)
          JCOL=INDEX(L,2)
          DO 549 K=1,N
          T=A(K,JROW)
          A(K,JROW)=A(K,JCOL)
          A(K,JCOL)=T
     549 CONTINUE
       3 CONTINUE
      81 RETURN
           END
```

END OF COMPILATION: NO DIAGNOSTICS.

TTDSM: Tape Transport Dynamic Simulation Model

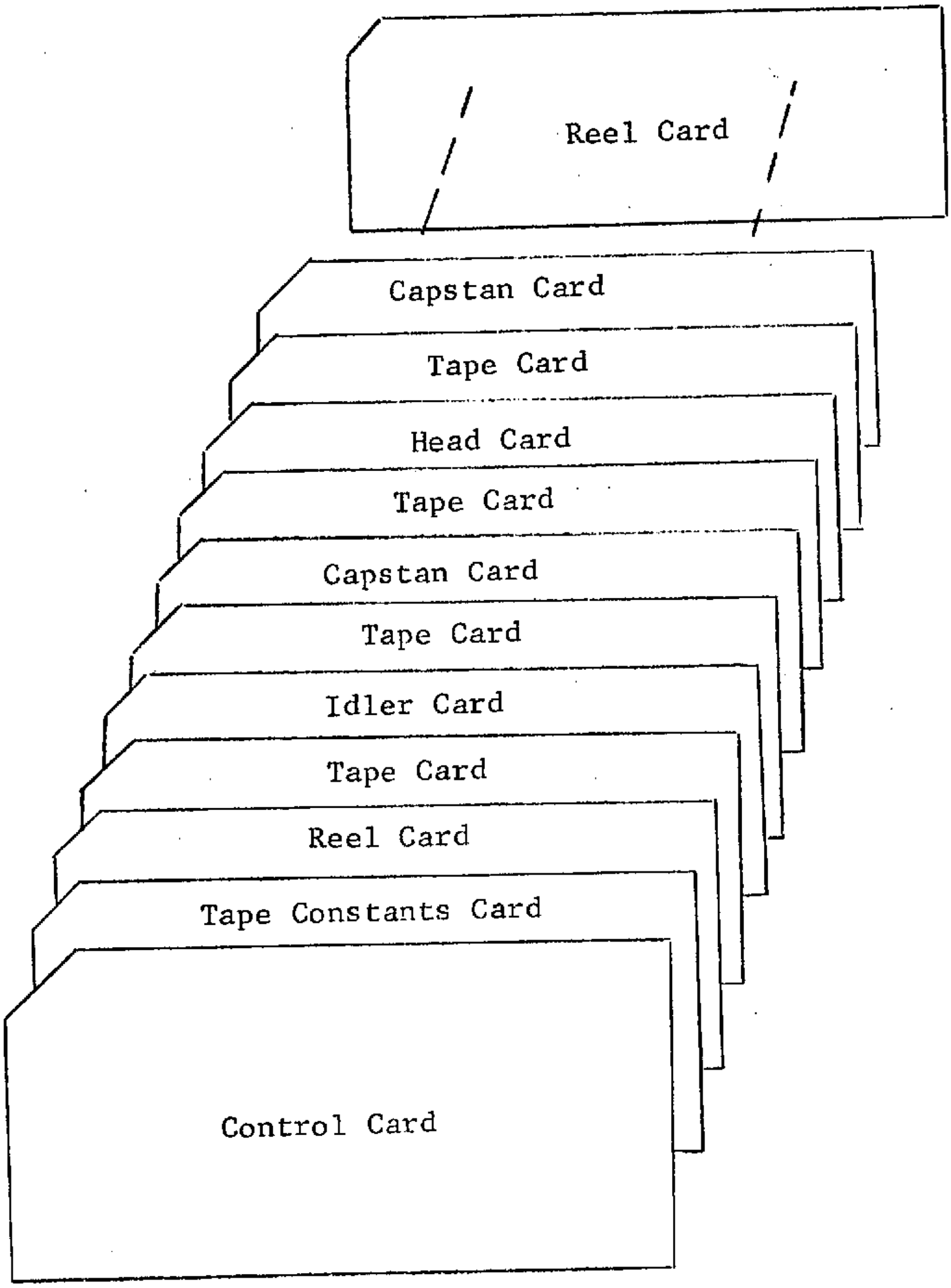


Figure E3 - Simulation Model Input Data Cards

CONTROL CARD

Code	Nomenclature	Field	Format	Units
DELT	Frequency Step Size	1-10	E10.5	Rad/Sec
TMAX	Stop Time	11-20	E10.5	Sec
AMT	Tape Length	21-30	E10.5	Feet
EC	Error Criterion	31-40	E10.5	Rad/Sec
SF	Starting Frequency	41-50	E10.5	Rad/Sec
N	Number of Frequency	51-53	I3	
K	Number of Data Sets	54-56	I3	
ISC1	Switch 1	57-59	I3	Note 1
ISC2	Switch 2	60-62		
FS	Frequency Interval	63-72	E1C.5	Rad/Sec
FL	Maximum Frequency	73-80	E8.3	Rad/Sec

Note 1: ISC1 = 1 for natural frequency calculation
ISC1 = 3 for linear forced response calculation

TAPE CONSTANTS CARD

Code	Nomenclature	Field	Format	Units
DENST	Tape Density	1-10	E10.5	lb/in
MODET	Modulus ofElasticity	11-20	E10.5	lb/in
THKT	Thickness	21-30	E10.5	in
WTHT	Width	31-40	E10.5	in
V	Tape Velocity	41-50	E10.5	in/sec

REEL, CAPSTAN, AND IDLER CARDS

Code	Nomenclature	Field	Format	Units
J	Next Element*	1	I1	
AJHUB	Inertia, total (hub & tape)	2-10	E9.4	$lb/in/sec^2$
RHUB	Radius (pack or hub)	11-19	E9.4	in
FDRAG	Drag Coefficient	20-28	E9.4	lb/in/sec
TS	Torque Perturbation (sine)	29-37	E9.4	in/lb
TC	Torque Perturbation (cosine)	38-46	E9.4	in/lb
AKD**	Flux	47-55	E9.4	
RA**	Resistance	56-64	E9.4	Ohms
VA**	Voltage	65-73	E9.4	Volts
M	Linear Subroutine Code	74	I1	
NA	Perturbation Ratio	75-77	I3	

* Next Element Code. Each of the following input cards requires a "next element" code to inform the computer of what type of data is to be read from the following card. The following integers are entered in the first data field column "J".

Enter J=1 to end reading

Enter J=2 if next element is a reel

Enter J=3 if next element is a capstan

Enter J=4 if next element is an idler

Enger J=5 if next element is a head

Enter J=6 if next element is a tape

Enter J=7 if next element is a reducer

The program assumes that the first card after the control and tape constant cards will be a reel.

** Equal to +0.0000 + 00 for idlers

$$\text{Flux} = \sqrt{K_T \, K_B}$$

where: K_T = torque sensitivity $\left(\frac{\text{in-oz}}{\text{amp}}\right)$

K_B = back EMF $\left(\frac{\text{volts-sec}}{\text{rad}}\right)$

TAPE CARD

Code	Nomenclature	Field	Format	Units
J	Next Element	1	I1	
TLL	Tape Length	2-10	E9.4	in
M	Linear Subroutine Code	11	I1	
CH	Head Constant	12-20	E9.4	lb/sec/in

HEAD CARD

Code	Nomenclature	Field	Format	Units
J	Next Element	1	I1	
FO	Static Friction	2-10	E9.4	lb
F1	Dynamic Friction	11-19	E9.4	lb/sec/in
CNN	Dynamic Friction (μ)	20-28	E9.4	
M	Linear Subrouting Code	29	I1	

LOW SPEED CAPSTAN REDUCER

Code	Nomenclature	Field	Format	Units
J	Next Element	1	I1	
BJHUB	Inertia	2-10	E9.4	lb/in/sec
GR	Gear Ratio	11-19	E9.4	C:1
BFDRAG	Drag Coefficient	20-28	E9.4	in/lb/sec
BKD	Flux	29-37	E9.4	
BRA	Resistance	38-46	E9.4	Ohms

Example Response Problem

The use of this computer program, TTDSM, is illustrated for one specific problem involving the five year high reliability tape transport. Figure E-4 shows a schematic figure of the transport with its dynamic properties. The disturbing forces are generated from eccentricities in the idlers and capstans.

The first example is the calculation of the natural frequencies of the system. The input data for the natural frequency calculation is shown in Figure E-5 as computer printout. All input data is always printed out prior to computation. The natural frequencies are obtained through a searching technique and therefore, the initial step size (delta) should be larger than 5.0 rad sec^{-1} and the starting frequency must be greater than zero. The searching technique ends either after the set number of frequencies or on the maximum frequency, while the error criterion is used to determine the natural frequency accuracy span. It should be noted that in these examples the tape mass is included and modeled in terms of an equivalent low inertia idler in the center of each system element. The resulting output data is shown in Figure E-6 where the natural frequency is given in hertz and the mode shape (theta) in radians.

The second illustrated example is that of the steady state vibrational response. The input data for this calculation is given in Figure E-7. Here the forcing frequency (a single frequency forcing function is allowed per data set) is shown as ST.FREQ., the damping constant on each mechanical component as DRAG COEF, and the forcing function amplitudes (sine and cosine components) to obtain proper phasing, if required, as PERT TORQ. Again, the tape mass is modeled in terms of a equivalent low inertia idler in the center of each system element. The output data shown in Figure E-8 tabulate the response (i.e., displacement) at each component in the transport in terms of amplitude and phase angle. These data also show the rms vibration velocity of each element of the transport.

Tape Data:

L = 1500 ft.

E = 650000 psi

t = 0.00112 in.

W = 1.0 in.

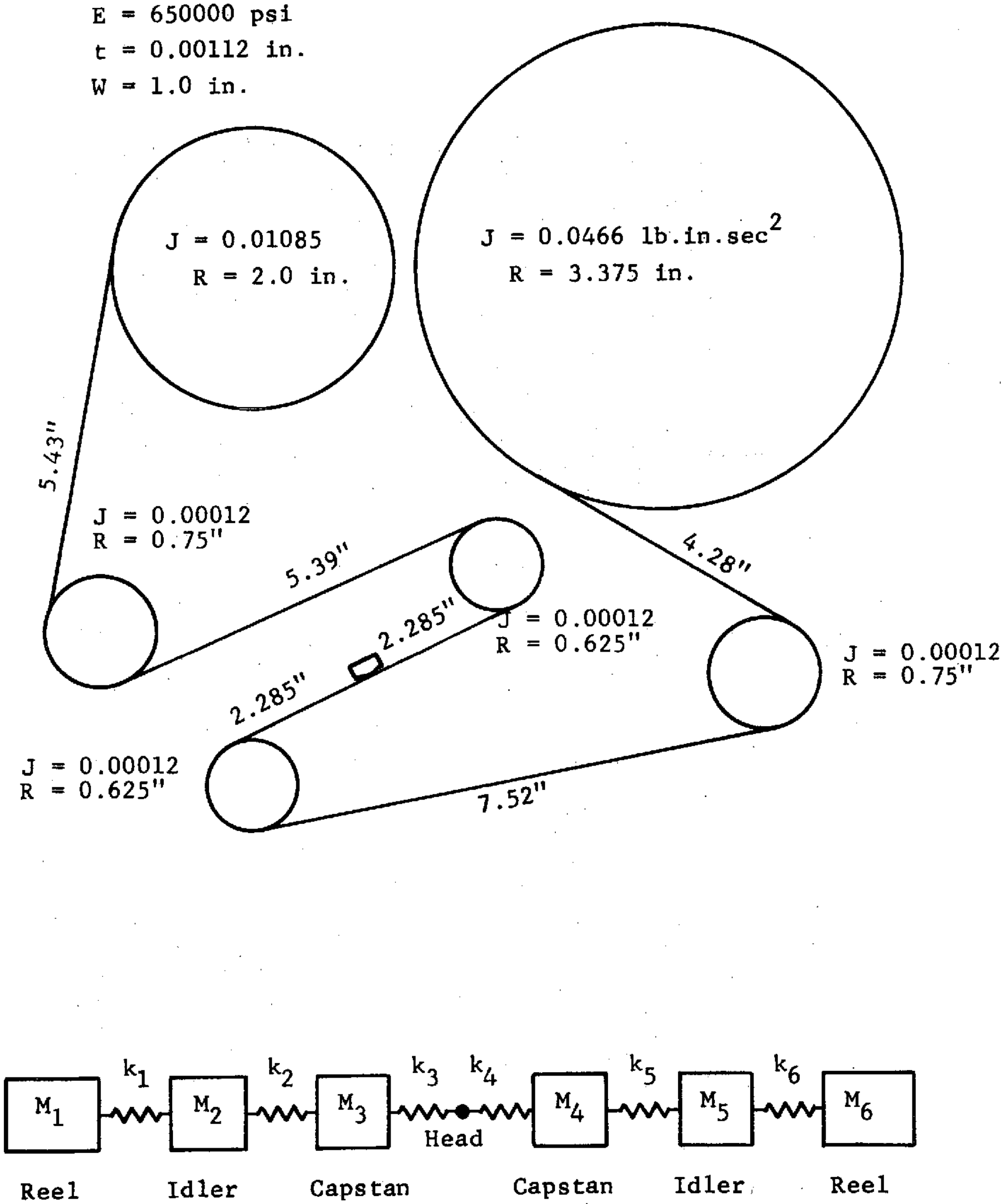


Figure E-4 TRANSPORT DYNAMIC PROPERTIES

Figure E-5

System Frequency Calculation Input Data

```
CONTROL INPUT DATA

DELTA= .50000+01      T MAX= .70000+00      AMI.TAPE= .15000+04      ERROR CRIT.= .10000+01      ST.FREQ= .40000+01
NO.FREQ=  6           NO.SETS=  1           SC1=  1                  SC2=  0                        FREQ.INT.= .00000
MAX.FREQUENCY= .400+04

TAPE INPUT DATA
DENSITY= .66000-01     MOD.ELST= .65000+06     THK.TAPE= .11200-02     WTH.TAPE= .10000+01     TAPE VEL= .30000+01

TAPE TRANSPORT INPUT DATA

REEL.CODE=6  INERT.HUB= .1085-01  R.HUB= .2000+01  DRAG COEF= .3820-02  PERT.TORQ(S)= .0000     PERT.TORQ(C)= .0000
     FLUX= .5880+01  RESIST= .6000+02  VOLTS= .0000     PT.CD=1  NA=  1


TAPE.CODE=4  TAPE LGTH= .2715+01  PT.CD=1


IDLER.CODE=6  INERT.HUB= .2183-06  R.HUB= .1000+01  DRAG COEF= .0000     PERT.TORQ(S)= .0000     PERT.TORQ(C)= .0000
 PT.CD=1  NA=  1


TAPE.CODE=4  TAPE LGTH= .2715+01  PT.CD=1


IDLER.CODE=6  INERT.HUB= .1200-03  R.HUB= .7500+00  DRAG COEF= .6960-03  PERT.TORQ(S)= .5970-04  PERT.TORQ(C)= .8000-04
 PT.CD=1  NA=  1


TAPE.CODE=4  TAPE LGTH= .2695+01  PT.CD=1


IDLER.CODE=6  INERT.HUB= .2183-06  R.HUB= .1000+01  DRAG COEF= .0000     PERT.TORQ(S)= .0000     PERT.TORQ(C)= .0000
 PT.CD=1  NA=  1


TAPE.CODE=3  TAPE LGTH= .2695+01  PT.CD=1


CAPSTAN.CODE=6  INERT.HUB= .1200-03  R.HUB= .6250+00  DRAG COEF= .5800-03  PERT.TORQ(S)= .0000     PERT.TORQ(C)= .0000
     FLUX= .1040+01  RESIST= .4000+02  VOLTS= .0000     PT.CD=1  NA=  1


TAPE.CODE=4  TAPE LGTH= .2285+01  PT.CD=1


IDLER.CODE=6  INERT.HUB= .2075-06  R.HUB= .1000+01  DRAG COEF= .2000-02  PERT.TORQ(S)= .0000     PERT.TORQ(C)= .0000
 PT.CD=1  NA=  1


TAPE.CODE=3  TAPE LGTH= .2285+01  PT.CD=1


CAPSTAN.CODE=6  INERT.HUB= .1200-03  R.HUB= .6250+00  DRAG COEF= .5800-03  PERT.TORQ(S)= .0000     PERT.TORQ(C)= .0000
     FLUX= .1040+01  RESIST= .4000+02  VOLTS= .0000     PT.CD=1  NA=  1
```

```
TAPE.CODE=4  TAPE LGTH= .3760+01  PT.CD=1

IDLER.CODE=6  INERT.HUB= .2183-06  R.HUB= .1000+01  DRAG COEF= .0000     PERT.TORQ(S)= .0000     PERT.TORQ(C)= .0000
 PT.CD=1  NA=  1

TAPE.CODE=4  TAPE LGTH= .3760+01  PT.CD=1

IDLER.CODE=6  INERT.HUB= .1200-03  R.HUB= .7500+00  DRAG COEF= .6960-03  PERT.TORQ(S)= .0000     PERT.TORQ(C)= .0000
 PT.CD=1  NA=  1

TAPE.CODE=4  TAPE LGTH= .2140+01  PT.CD=1

IDLER.CODE=6  INERT.HUB= .2183-06  R.HUB= .1000+01  DRAG COEF= .0000     PERT.TORQ(S)= .0000     PERT.TORQ(C)= .0000
 PT.CD=1  NA=  1

TAPE.CODE=2  TAPE LGTH= .2140+01  PT.CD=1

REEL.CODE=1  INERT.HUB= .4660-01  R.HUB= .3375+01  DRAG COEF= .3820-02  PERT.TORQ(S)= .0000     PERT.TORQ(C)= .0000
     FLUX= .5880+01  RESIST= .6000+02  VOLTS= .0000     PT.CD=1  NA=  1
```

Figure E-5 Continued

Figure E-6

Frequency Calculation Output Data

NATURAL FREQUENCY NO. 1 = .20034+02 HZ

NATURAL FREQUENCY CALCULATION

STATION	THETA(RAD)	TORQUE(IN-LB)
1	.5000+00	.0000
2	.8397+00	.4298+02
3	.9059+00	.4298+02
4	.5118+00	.4528+02
5	.5507+00	.4528+02
6	.1968+00	.4695+02
7	.7909-01	.4696+02
8	-.1943+00	.4720+02
9	-.5841+00	.4720+02
10	-.5725+00	.4571+02
11	-.2094+00	.4571+02

Figure E-6 Continued

NATURAL FREQUENCY NO. 2 = .72654+02 HZ

NATURAL FREQUENCY CALCULATION

STATION	THETA(RAD)	TORQUE(IN-LB)
1	.5000+00	.0000
2	-.1108+01	.5653+03
3	-.4288+01	.5652+03
4	-.4779+01	.4222+03
5	-.1015+02	.4220+03
6	-.6392+01	.1606+02
7	-.1031+02	.1578+02
8	-.4393+01	-.3966+03
9	-.3125+01	-.3968+03
10	-.8711+00	-.5010+03
11	.1783+00	-.5010+03

Figure E-6 Continued

NATURAL FREQUENCY NO. 3 = .15069+03 HZ

NATURAL FREQUENCY CALCULATION

STATION	THETA(RAD)	TORQUE(IN-LB)
1	.5000+00	.0000
2	-.8069+01	.2432+04
3	-.2284+02	.2430+04
4	-.1400+02	-.8462+03
5	-.1737+02	-.8489+03
6	.1192+01	-.3839+04
7	.2118+02	-.3838+04
8	.1423+02	-.1923+03
9	.2028+02	-.1895+03
10	.7217+01	.2720+04
11	-.2316+00	.2721+04

Figure E-6 Continued

NATURAL FREQUENCY NO. 4 = .19142+03 HZ

NATURAL FREQUENCY CALCULATION

STATION	THETA(RAD)	TORQUE(IN-LB)
1	.5000+00	.0000
2	-.1363+02	.3924+04
3	-.3767+02	.3920+04
4	-.1049+02	-.4799+04
5	.1167+02	-.4802+04
6	.1219+02	-.1562+04
7	.2733+02	-.1558+04
8	-.1408+02	.6034+04
9	-.6030+02	.6030+04
10	-.2192+02	-.7927+04
11	.4146+00	-.7934+04

Figure E-6 Continued

NATURAL FREQUENCY NO. 5 = .21525+03 HZ

NATURAL FREQUENCY CALCULATION

STATION	THETA(RAD)	TORQUE(IN-LB)
1	.5000+00	.0000
2	-.1750+02	.4961+04
3	-.4797+02	.4954+04
4	-.2347+01	-.9085+04
5	.5006+02	-.9086+04
6	.4626+01	.8495+04
7	-.3527+02	.8497+04
8	-.1955+01	-.3889+04
9	.2418+02	-.3890+04
10	.8769+01	.3187+04
11	-.1805+00	.3190+04

Figure E-6 Continued

NATURAL FREQUENCY NO. 6 = .78895+04 HZ

NATURAL FREQUENCY CALCULATION

STATION	THETA(RAD)	TORQUE(IN-LB)
1	.5000+00	.0000
2	-.2486+05	.6665+07
3	.1711+02	-.6669+07
4	-.2076+03	.5954+05
5	-.2524+02	-.5181+05
6	.3753+05	-.1196+08
7	.2402+05	.7174+07
8	-.5855+08	.1134+11
9	.6014+08	-.2007+11
10	-.6940+11	.2363+14
11	-.8715+10	-.1360+14

Figure E-7

System Response Calculation Input Data

```
CONTROL INPUT DATA

DELTA= .50000+01      T MAX= .70000+00      AMT.TAPE= .15000+04      ERROR CRIT.= .10000+01      ST.FREQ= .40000+01
NO.FREQ= 1            NO.SETS= 4            SC1= 3                   SC2= 0                         FREQ.INT.= .00000
MAX.FREQUENCY= .200+04

TAPE INPUT DATA
DENSITY= .66000-01     MOD.ELST= .65000+06     THK.TAPE= .11200-02     WTH.TAPE= .10000+01     TAPE VEL= .30000+01

TAPE TRANSPORT INPUT DATA

REEL.CODE=6  INERT.HUB= .1085-01  R.HUB= .2000+01  DRAG COEF= .3820-02  PERT.TORQ(S)= .0000     PERT.TORQ(C)= .0000
     FLUX= .5880+01  RESIST= .6000+02  VOLTS= .0000     PT.CD=1  NA= 1

TAPE.CODE=4  TAPE LGTH= .2715+01  PT.CD=1  HEAD COEF.= .0000

IDLER.CODE=6  INERT.HUB= .2183-06  R.HUB= .1000+01  DRAG COEF= .0000     PERT.TORQ(S)= .0000     PERT.TORQ(C)= .0000
    PT.CD=1  NA= 1

TAPE.CODE=4  TAPE LGTH= .2715+01  PT.CD=1  HEAD COEF.= .0000

IDLER.CODE=6  INERT.HUB= .1200-03  R.HUB= .7500+00  DRAG COEF= .6960-03  PERT.TORQ(S)= .5970-04  PERT.TORQ(C)= .8000-04
    PT.CD=1  NA= 1

TAPE.CODE=4  TAPE LGTH= .2695+01  PT.CD=1  HEAD COEF.= .0000

IDLER.CODE=6  INERT.HUB= .2183-06  R.HUB= .1000+01  DRAG COEF= .0000     PERT.TORQ(S)= .0000     PERT.TORQ(C)= .0000
    PT.CD=1  NA= 1

TAPE.CODE=3  TAPE LGTH= .2695+01  PT.CD=1  HEAD COEF.= .0000

CAPSTAN.CODE=6  INERT.HUB= .1200-03  R.HUB= .6250+00  DRAG COEF= .5800-03  PERT.TORQ(S)= .0000     PERT.TORQ(C)= .0000
     FLUX= .1040+01  RESIST= .4000+02  VOLTS= .0000     PT.CD=1  NA= 1

TAPE.CODE=4  TAPE LGTH= .2285+01  PT.CD=1  HEAD COEF.= .0000

IDLER.CODE=6  INERT.HUB= .2075-06  R.HUB= .1000+01  DRAG COEF= .2000-02  PERT.TORQ(S)= .0000     PERT.TORQ(C)= .0000
    PT.CD=1  NA= 1

TAPE.CODE=3  TAPE LGTH= .2285+01  PT.CD=1  HEAD COEF.= .0000

CAPSTAN.CODE=6  INERT.HUB= .1200-03  R.HUB= .6250+00  DRAG COEF= .5800-03  PERT.TORQ(S)= .0000     PERT.TORQ(C)= .0000
     FLUX= .1040+01  RESIST= .4000+02  VOLTS= .0000     PT.CD=1  NA= 1
```

```
TAPE.CODE=4  TAPE LGTH= .3760+01  PT.CD=1  HEAD COEF.= .0000

IDLER.CODE=6  INERT.HUB= .2183-06  R.HUB= .1000+01  DRAG COEF= .0000     PERT.TORQ(S)= .0000     PERT.TORQ(C)= .0000
    PT.CD=1  NA=  1

TAPE.CODE=4  TAPE LGTH= .3760+01  PT.CD=1  HEAD COEF.= .0000

IDLER.CODE=6  INERT.HUB= .1200-03  R.HUB= .7500+00  DRAG COEF= .6960-03  PERT.TORQ(S)= .0000     PERT.TORQ(C)= .0000
    PT.CD=1  NA=  1

TAPE.CODE=4  TAPE LGTH= .2140+01  PT.CD=1  HEAD COEF.= .0000

IDLER.CODE=6  INERT.HUB= .2183-06  R.HUB= .1000+01  DRAG COEF= .0000     PERT.TORQ(S)= .0000     PERT.TORQ(C)= .0000
    PT.CD=1  NA=  1

TAPE.CODE=2  TAPE LGTH= .2140+01  PT.CD=1  HEAD COEF.= .0000

REEL.CODE=1  INERT.HUB= .4660-01  R.HUB= .3375+01  DRAG COEF= .3820-02  PERT.TORQ(S)= .0000     PERT.TORQ(C)= .0000
     FLUX= .5880+01  RESIST= .6000+02  VOLTS= .0000     PT.CD=1  NA=  1
```

Figure E-7 Continued

```
SET NO.  1 RESPONSE OUTPUT

ELEMENT NO.  1     RESPONSE= .00000     INCHES
ELEMENT NO.  2     RESPONSE= .23430-15  INCHES     RESPONSE AMPLITUDE= .23430-15 INCHES     PHASE=     .0000 RAD.

ELEMENT NO.  3     RESPONSE= .00000     INCHES
ELEMENT NO.  4     RESPONSE=-.88818-15  INCHES     RESPONSE AMPLITUDE= .88818-15 INCHES     PHASE=     .0000 RAD.

ELEMENT NO.  5     RESPONSE= .00000     INCHES
ELEMENT NO.  6     RESPONSE=-.35527-14  INCHES     RESPONSE AMPLITUDE= .35527-14 INCHES     PHASE=     .0000 RAD.

ELEMENT NO.  7     RESPONSE= .80000-04  INCHES
ELEMENT NO.  8     RESPONSE=-.17764-14  INCHES     RESPONSE AMPLITUDE= .80000-04 INCHES     PHASE=   -1.5708 RAD.

ELEMENT NO.  9     RESPONSE= .78063-17  INCHES
ELEMENT NO. 10     RESPONSE= .11102-14  INCHES     RESPONSE AMPLITUDE= .11103-14 INCHES     PHASE=     .0070 RAD.

ELEMENT NO. 11     RESPONSE=-.20126-05  INCHES
ELEMENT NO. 12     RESPONSE=-.35359-06  INCHES     RESPONSE AMPLITUDE= .20434-05 INCHES     PHASE=    1.3969 RAD.

ELEMENT NO. 13     RESPONSE= .17764-14  INCHES
ELEMENT NO. 14     RESPONSE=-.11315-05  INCHES     RESPONSE AMPLITUDE= .11315-05 INCHES     PHASE=    -.0000 RAD.

ELEMENT NO. 15     RESPONSE= .00000     INCHES
ELEMENT NO. 16     RESPONSE= .00000     INCHES     RESPONSE AMPLITUDE= .00000    INCHES     PHASE=     .0000 RAD.

ELEMENT NO. 17     RESPONSE= .00000     INCHES
ELEMENT NO. 18     RESPONSE= .00000     INCHES     RESPONSE AMPLITUDE= .00000    INCHES     PHASE=     .0000 RAD.

ELEMENT NO. 19     RESPONSE= .00000     INCHES
ELEMENT NO. 20     RESPONSE= .00000     INCHES     RESPONSE AMPLITUDE= .00000    INCHES     PHASE=     .0000 RAD.

ELEMENT NO. 21     RESPONSE= .00000     INCHES
ELEMENT NO. 22     RESPONSE= .00000     INCHES     RESPONSE AMPLITUDE= .00000    INCHES     PHASE=     .0000 RAD.
```

Figure E-8   Response Output Data

APPENDIX F

CONTROL SYSTEM ELECTRONICS DESCRIPTION

APPENDIX F
CONTROL SYSTEM ELECTRONICS
DESCRIPTION

SPEED CONTROL SYSTEM

Speed-Capstan Drive Servo

The schematic diagram of the speed control panel is shown in Figure F-1. Operational amplifier A401 (Fairchild type μA748TC) sums the velocity-command voltage, $-\dot{X}_c$ (from Figure F-3), and the measured-velocity voltage, $\dot{X}$ (from Figure F-2), via R401 and R402, respectively, to serve as the comparator; and also functions as the augmenting integrator by virtue of its feedback through R406 and C405. At frequencies above 70 Hz (established by R406 and C405), the voltage gain of this amplifier from either $\dot{X}$ or $-\dot{X}_c$ (each of which has a scale factor of 100 millivolts per inch/second of tape speed) to pin 6 of Q401 is -47; while at frequencies below 70 Hz, the magnitude of this gain varies inversely with frequency. The output of Q401 is applied via relay contact K401A (to permit turning off motor drive in standby mode -- see section 2.2.5 Vol. II) to R410 which provides means for adjusting the servo loop gain over a range of about 20 dB.

Operational power amplifier Q410 (Inland Controls model IC-50) is connected as indicated in the basic circuit of Figure F-10 to form a transconductance amplifier. The motor armature is connected between pins 12 and 24 of J401, R422 is the current-sensing resistor, R419 is the feedback resistor, and R412 is the input resistor. The overall "gain" or transconductance of this amplifier from its input voltage at the wiper of R410 to motor current is -0.347 amps/volt. For the motor's (Magnetic Technology model 1937-050-115) nominal torque constant of 10.4 oz-in/amp, this gain translates to -3.61 oz-in/volt. To make the net useful output torque of the motor propor-

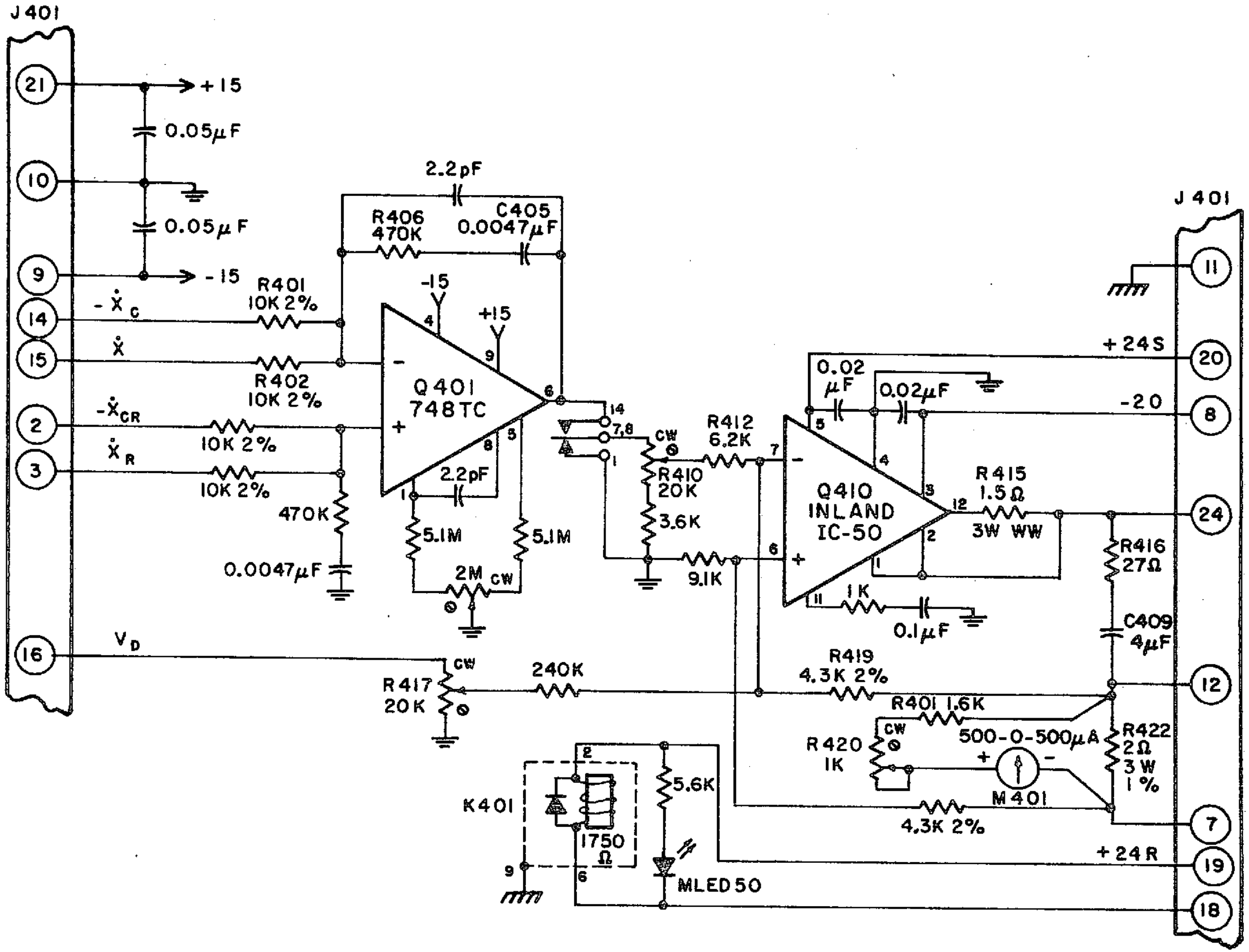


Fig. F-1 SCHEMATIC CIRCUIT DIAGRAM OF SPEED-CONTROL PANEL

tional to amplifier input voltage in the presence of bearing and brush/commutator friction drag, a small offset input giving rise to a torque equal to the drag torque is provided through R418 and set with R417. Resistor R415 sets the peak amplifier output current limit at about ± 0.595 amperes which, in turn, limits peak motor torque to ± 6.19 ounce-inches. Sensitivity of meter M401 is set with R420 and R421 to produce an indication of 500 µA (full scale) when the motor is developing a torque of 5 ounce-inches to facilitate direct reading of total torque.

Tachometer Processing (Figure F-2)

The frequency-to-voltage converter consists of a pulse standardizer that produces two zero-based, stabilized-energy pulses per cycle of A or B from the tachometer; and a low-pass filter that extracts the average value of these pulses (which is proportional to pulse frequency and, thus, capstan speed). Pulse energy is stabilized to provide calibration stability, and this is achieved by making the pulses rectangular and accurately maintaining both pulse width and amplitude.

The $\overline{A}$ and $\overline{B}$ (inverted due to line-driving inverters on transport -- see Figure F-8) signals from the tachometer enter the processing circuitry on pins 6 and 24, respectively,of J106. Due to the action of NAND gates Q18B and Q18C (each 1/4 of type 74L00) and the input OR gate of monostable multivibrator Q16 (type 74121), the latter is triggered on both positive and negative transitions of B (or $\overline{B}$) in the forward (record) direction, and of A (or $\overline{A}$) in the reverse (play) direction. Each time Q16 is triggered, it produces a positive-going rectangular pulse about 8 µ seconds wide at pin 6. The width of this pulse is directly related to the product of C30 and the sum of R31 and R32, and is essentially independent of the termperature of Q16 and moderate changes in supply voltage. However, the pulse is not zero based (i.e., output amplitude between pulses is not zero) and its amplitude is not accurately established, so

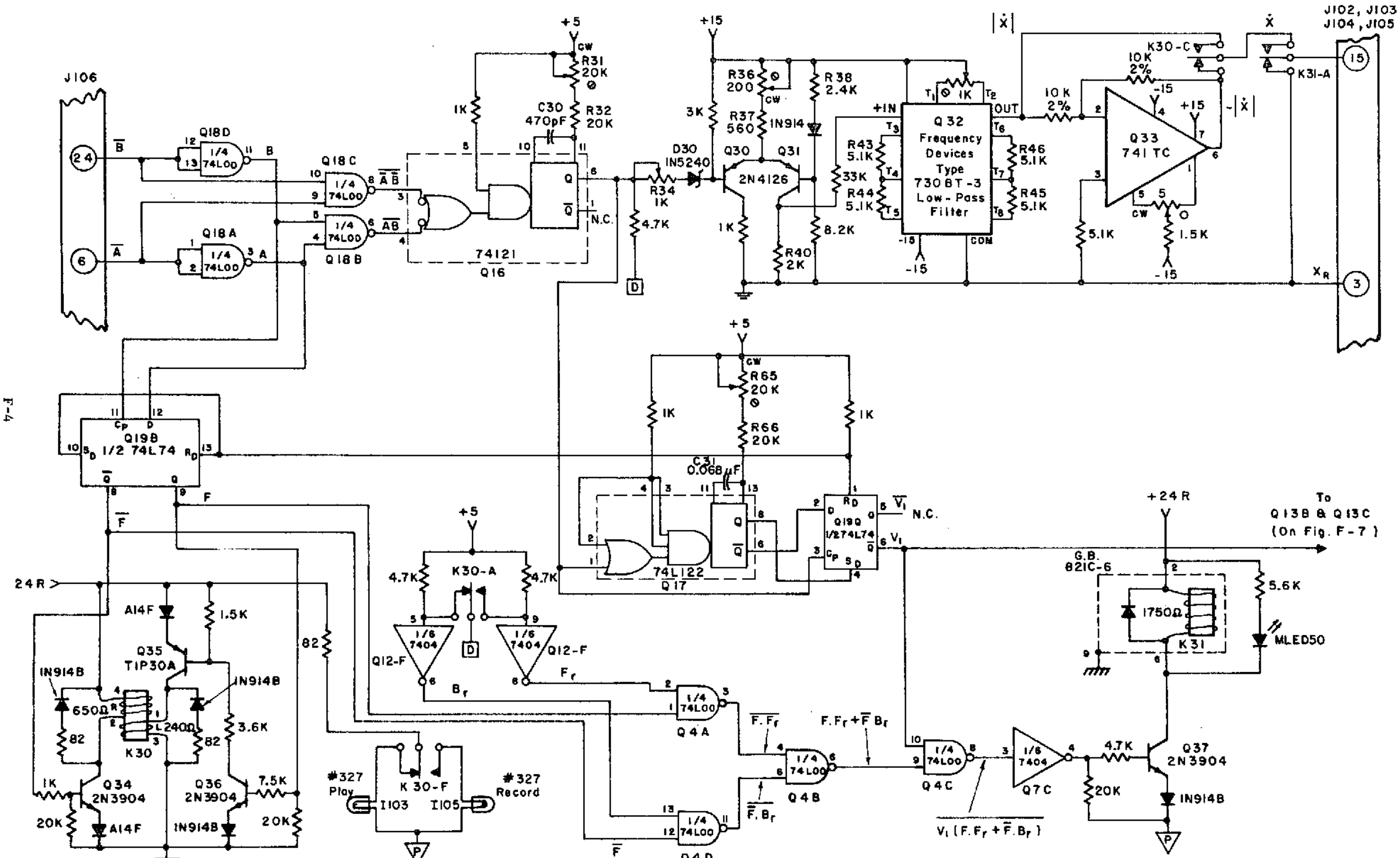


Fig. F-2 SCHEMATIC DIAGRAM OF TACHOMETER PROCESSING CIRCUITRY

the circuitry involving transistors Q30 and Q31 (each type 2N4126) is employed to impart these characteristics.

Between pulses, when the voltage at pin 6 of Q16 is low, the base voltage of Q30 is pulled sufficiently below the fixed base voltage of Q31 (about +11 volts) that Q30 is turned on and draws all of the current flowing through R36 and R37. As a consequence, Q31 is cut off and there is <u>no</u> voltage developed across R40 -- thus providing the required zero base for the pulses. During each pulse, when the voltage at pin 6 of Q16 is high, the base voltage of Q31 such that Q30 is cut off and all of the current flowing through R36 and R37 is drawn by Q31 through R40 to develop a stable pulse amplitude of about 10 volts. This amplitude is inversely related to the sum of R36 and R37, and is essentially independent of moderate variations in the characteristics of Q31.

The standardized pulses developed across R40 are passed through a noniverting, unity-gain active low-pass filter (Frequency Devices type 730BT-3) to obtain their average value. Cutoff frequency of this filter in Hertz is $10{,}000/(R_z+5)$ where R_z is the resistance in kilohms of R43, R44, R45, and R46. Thus, with the 5.1-Kohm resistors used, cutoff frequency is about 1000 Hz. The scale factor of the output voltage from the filter is adjusted (with R31 and R36) to be 100 millivolts per inch/second of tape speed ($\dot{X}$).

The pulses developed across R40 are always positive, regardless of direction of tape travel. Thus the signal out of the filter also is always positive and proportional to the absolute magnitude of tape speed, $|\dot{X}|$. To provide the polarity-sensitive speed signal, $\dot{X}$, required by the speed-control servo, the filter output is passed through an analog unity-gain inverting amplifier employing Q33 (Fairchild type μA741TC) and relay contact K30-C is used to select the proper signal polarity. Thus, in the forward (record) direction, the relay is operated and

the filter output is used for $\dot{X}$; while in the reverse (play) direction, the relay is released and the inverter output is used for $\dot{X}$.

The polarity of the phase difference between A and B tachometer signals is sensed with D-type flip-flop Q19B (1/2 of type 74L74) which stores and reproduces at its pin-9 output (F) the level of its pin-12 input (A), each time its pin-11 input (B) makes a positive transition. Thus its pin-9 output (F) is high in the forward (record) direction, and its pin-8 output ($\overline{F}$) is high in the reverse (play) direction. These two outputs are used to drive (via transistors Q34, Q35, and Q36) relay K30 which, in turn, effects the polarity switching of the $\dot{X}$ signal mentioned above, as well as several other direction-related switching operations. A magnetically-latching relay (Automatic Electric series HRM, cat. no. HF-26) is used for K30 to provide the nonvolatile memory of direction required for the power-off dynamic braking of the reel motors (see section 2.2.4.5, Vol. II).

Although filter Q32 effectively attenuates the pulse-rate ripple in the $\dot{X}$ signal at even the minimum operating tape speed of 3 inches/second, the ripple becomes quite large at lower speeds. To prevent these high-ripple levels from entering the speed-control servo, the $\dot{X}$ output from K30-C is switched off by relay contact K31-A whenever tape speed magnitude is below about 1.6 inches/second. This relay contact also is used to prevent the wrong polarity $\dot{X}$ signal from being applied to the servo (which would result in positive feedback) even briefly when K30 is changing state.

The state of K30 is sensed with its contact K30-A which gives rise to a high output (F_r) at pin 8 of inverter Q12-F (1/6 of type 7404) when K30 is latched (operated), and a high output (B_r) at pin 6 of inverter Q12-E (1/6 of type 7404) when

K30 is released. These signals are compared with sensed-direction signals F and $\overline{F}$ in NAND gates Q4A, Q4D, and Q4B (each 1/4 of type 74L00) to yield a signal to pin 6 of Q4B that is high only when the relay state corresponds to the actual direction. Retriggerable monostable multivibrator Q17 (type 74L122) and D-type flip-flop Q19A (1/2 of type 74L74) are combined to form a frequency or pulse-rate threshold detector, which produces a high output (V_1) at pin 6 of Q19A only when the input pulse rate (from pin 6 of Q16) exceeds about 2000 per second. This threshold corresponds to a tape speed of 1.57 in/sec, and is set with R65. Finally, NAND gate Q4C (1/4 of type 74L00) combines the V_1 and K30-state-verification signals to cause K31 (G.B. 821C-6 reed type) to be operated (via inverter Q7C and transistor Q37) only when K30 is in the proper state and tape speed is greater than about 1.6 inches/second.

Speed-Command Generator (Figure F-3)

Speeds in the slow and fast ranges are selected by manually setting the panel-mounted variable resistors R84 and R81, respectively. In the record mode, relay contact K1-D is operated and applies +15 volts to one of these two resistors, depending on which speed range is selected with toggle switch S81. In the play mode, relay contact K2-D is operated and applies -15 volts to only the fast-range resistor, R81. For a constant or slowly-varying voltage at the arm of either R81 or R84, the three operational amplifiers, Q82, Q83, and Q84 (each Fairchild type μA741TC) behave as a single operational amplifier to produce a proportional output voltage ($-\dot{X}_c$) at pin 6 of Q84 (and pin 14 of J103 and J104). The voltage gain is defined by the input summing resistors R82 and R85, and feedback resistor R91. Thus, R84 permits adjusting the DC voltage at pin 6 of Q84 from about -0.2 to -1.0 volts (record mode only); while R81 permits adjusting this voltage from about -2 to -8.3 volts in the record mode and about +2 to +8.3 volts in the play mode. The scale factor relating these output voltages ($-\dot{X}_c$) to speed is -10 in/sec per volt (or -100 millivolts per in/sec),

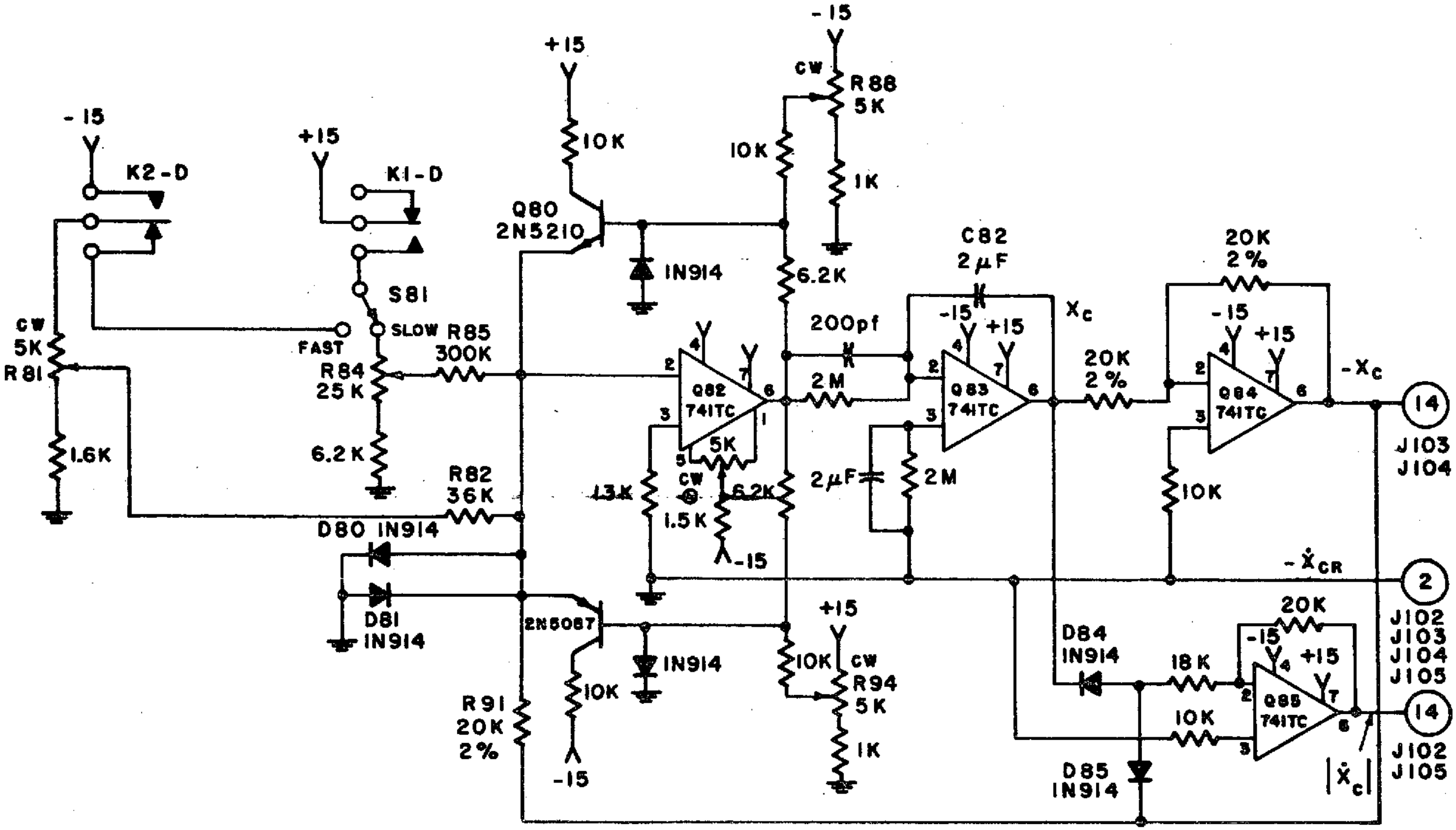


Fig. F-3 SCHEMATIC CIRCUIT DIAGRAM OF SPEED-COMMAND GENERATOR

where positive velocity is defined to be motion in the record direction.

Operational amplifier Q84 is connected as a unity-gain inverter, so the output of Q83 is simply $\dot{X}_c$ with a scale factor of 10 in/sec per volt. Operational amplifier Q83 is connected as an inverting integrator with a gain of -1/4 per second, so the output of Q82 is $-\ddot{X}_c$ with a scale factor of 2.5 in/sec^2 per volt. Thus the rate limit of $\dot{X}_c$, or the maximum tape acceleration, is established by limiting the output voltage of Q82. This action is performed by a pair of active feedback limiters consisting of Q80, Q81, and their associated components. Variable resistor R88 permits adjusting the voltage limit of Q82's output from about +2.4 to +10.3 volts, which corresponds to an acceleration range of about -6 to -26 in/sec^2; while variable resistor R94 permits adjusting the opposite-polarity limits over the same ranges.

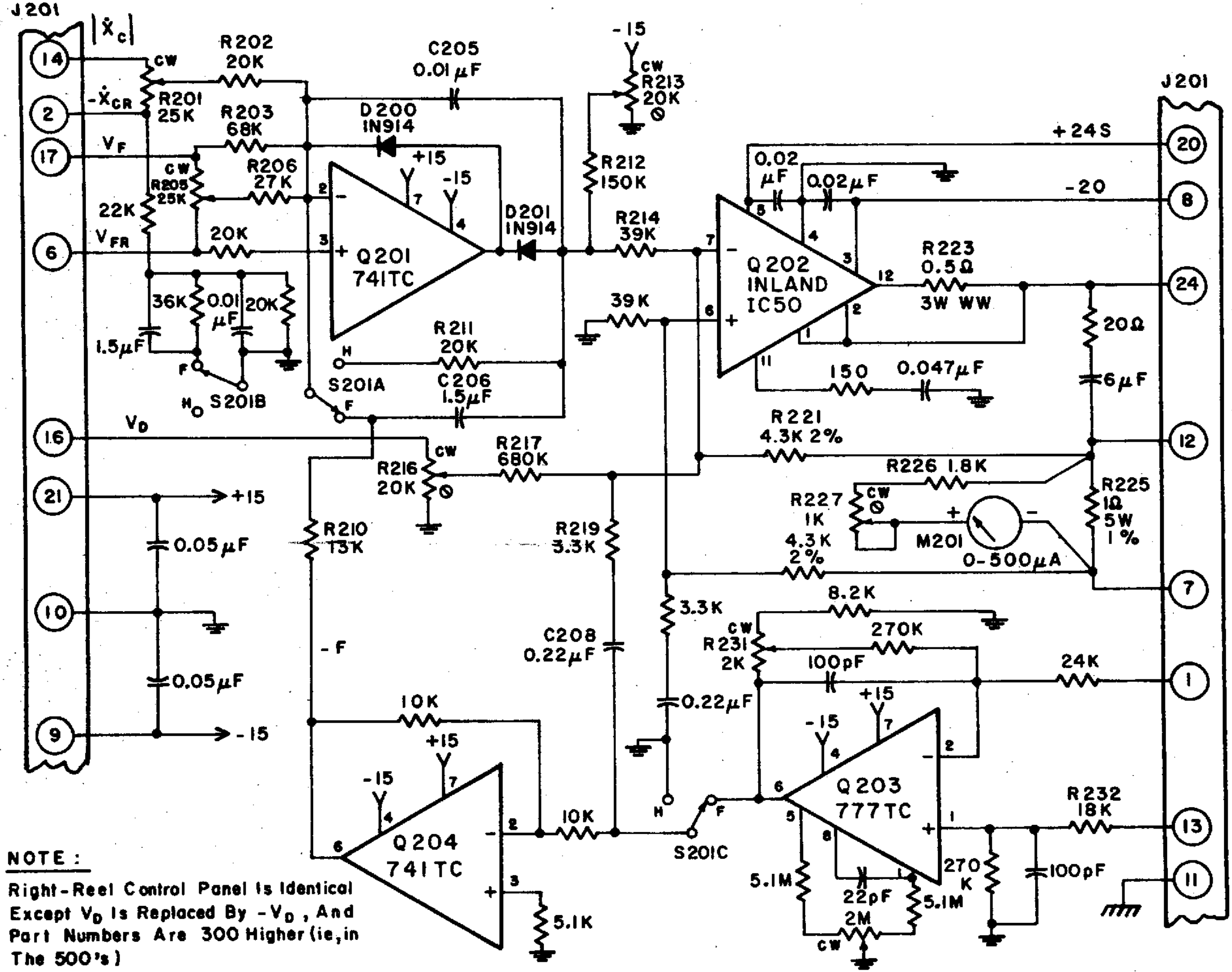
Operational amplifier Q85 (Fairchild type µA741TC) is connected as a unity-gain inverting full-wave rectifier to provide a signal approximately proportional to the absolute magnitude of $\dot{X}_c$ (i.e., $|\dot{X}_c|$) for use as a secondary input to the reel-drive servos. Due to the 0.6 to 0.7-volt inherent threshold of the diodes D84 and D85 (each type IN914), the output of Q85 is linearly related to the magnitude of commanded speeds only for speeds greater than ± 6 or 7 inches/sec, and is zero for lower speeds.

TENSION CONTROL SYSTEM

Reel-Drive Servos

When switch S201 (having three poles: S201A, S201B, and S201C) is is position F (see Figure F-4), the circuit configuration is that of a Tension-Control Servo which operates as follows.

Operational amplifier Q201 (Fairchild type µA741TC) sums the primary and secondary tension-command voltages (adjusted



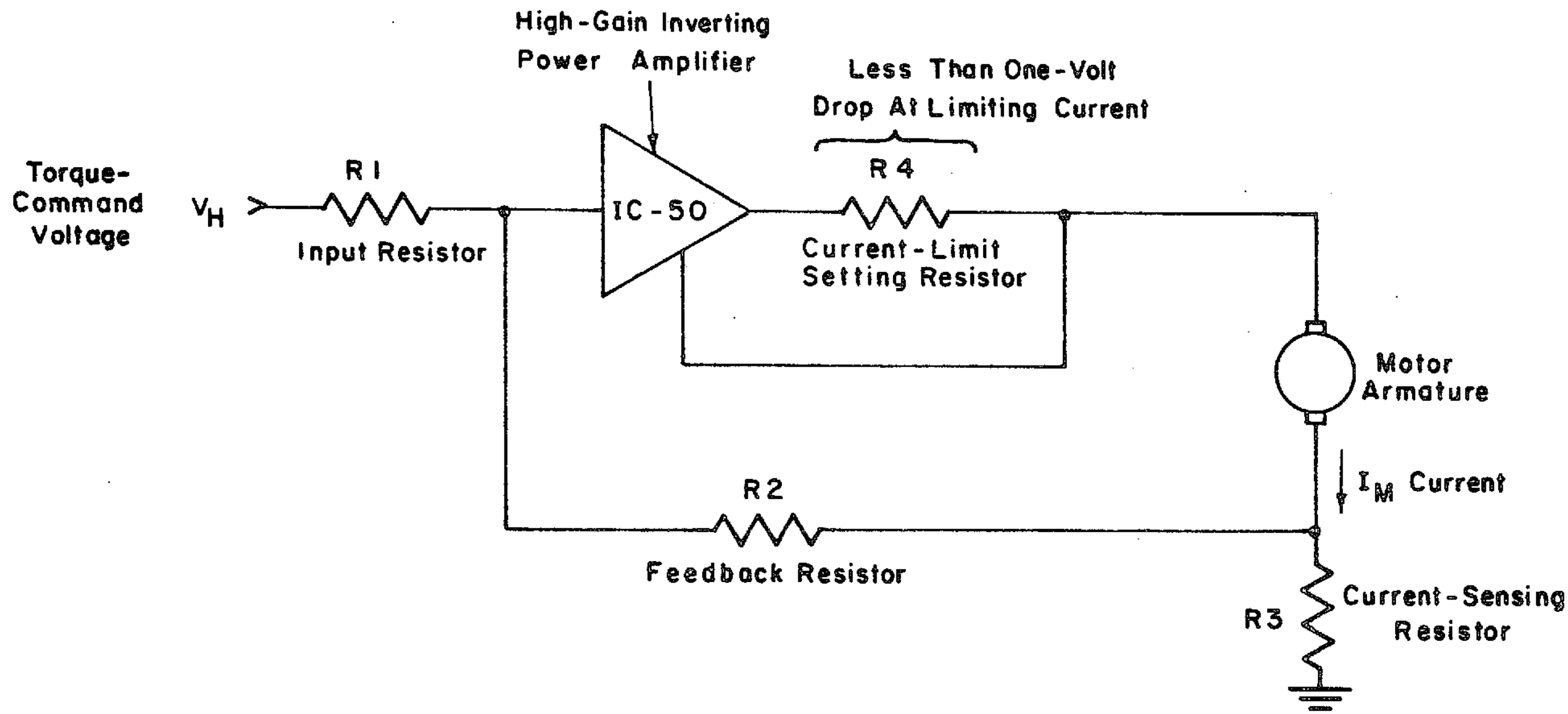
NOTE:

Right-Reel Control Panel Is Identical Except V_D Is Replaced By $-V_D$, And Part Numbers Are 300 Higher (ie, in The 500's)

Fig. F-4 SCHEMATIC CIRCUIT DIAGRAM OF LEFT-REEL CONTROL PANEL

with R205 and R201 respectively), and the measured-tension voltage, -F, via resistors R202, R203, R206, and R210 to serve as the comparator; and also functions as the integrator by virtue of its feedback through C206 (and C205). The voltage gain of this amplifier from -F to the junction of R212 and R214 is unity (with -90° phase shift) at 8 Hz, and varies inversely with frequency. Diode D201 is employed to prevent Q201 from ever developing a positive input (corresponding to a negative torque command) to the power amplifier Q202; and diode D200 simply prevents Q201 from saturating when D201 is not conducting.

Operational power amplifier Q202 (Inland Controls model IC-50) is connected as indicated in the basic circuit of Figure F-5 to form a transductance amplifier. The motor armature is connected between pins 12 and 24 of J201, R225 is the current-sensing resistor, R221 is the feedback resistor, and R214 is the input resistor. The torque-command input voltage (at junction of R212 and R214) for this power amplifier normally is produced by Q201, but a minimum input limit is established by R212 and the setting of R213 to provide a small residual torque and tape tension in the standby mode when the output from Q201 tends to go to zero. The overall "gain" or transductance of the power amplifier from its input voltage at the junction of R212 and R214 to motor current is -0.110 amps/volt. For the motor's (Magnetic Technology model 3000B-065-110) nominal torque constant of 39 oz-in/amp, this gain translates to -4.30 oz-in/volt. To make the net useful output torque of the motor proportional to amplifier input voltage in the presence of bearing and brush/commutator friction drag, a small offset input causing a torque equal to the drag torque is provided through R217 and set with R216. Resistor R223 sets the peak amplifier output current limit at about ± 1.47 amperes which, in turn, limits peak motor torque to ± 57.4 ounce-inches. Sensitivity of meter M201 is set with R226 and R227 to produce an indication of 500 μA (full



For $R2 \gg R3$: $I_M = V_H \dfrac{-R2}{R1\,R3}$

Fig. F-5 BASIC CIRCUIT OF TRANSCONDUCTANCE POWER AMPLIFIER AND DC MOTOR

scale) when the motor is developing a torque of 50 ounce-inches to facilitate direct reading of total torque.

Output from the tension-sensing instrument, having a scale factor of about 40 millivolts per ounce of tape tension, appears at pin 13 of J201 and is amplified by operational amplifier Q203 (Fairchild type μA777TC). Gain of this amplifier is set with R231 to produce a scale factor at its output (pin 6 of Q203) of 500 millivolts per ounce of tape tension. This signal is then fed back to the power amplifier through C203 and R219 to provide phase-lead damping, and is inverted by operational amplifier Q204 (Fairchild type μA741TC) to provide the proper polarity for closing the tension-control loop.

When switch S201 is in position H, the circuit configuration is transformed to that of an open-loop torque-control system by disconnecting the feedback from the tension sensor (at output of Q203) and changing Q201 to an amplifier by substituting R211 for C206 as its feedback impedance. In this torque-control configuration, Q201 simply sums the primary and secondary tension-command inputs to yield a proportional torque-command voltage.

<u>Tension-Capstan Control</u> (Figure F-6)

Operational power amplifier Q301 (Inland Controls Model IC-50) is connected as indicated in the basic circuit of Figure F-10 to form a transconductance amplifier. The motor armature is connected between pins 12 and 24 of J301, R310 is the current-sensing resistor, R311 is the feedback resistor, and R302 is the input resistor. The torque or tension-increment command input voltage (at arm of S301) for this power amplifier is zero when S301 is off, and is set with R301 when S301 is on. The overall "gain" or transconductance of the power amplifier, from its input voltage to motor current, is -0.055 amps/volt for the motor's (Magnetic Technology Model 1937-050-115) nominal torque constant of 10.4 oz-in/amp. This gain translates to -0.573

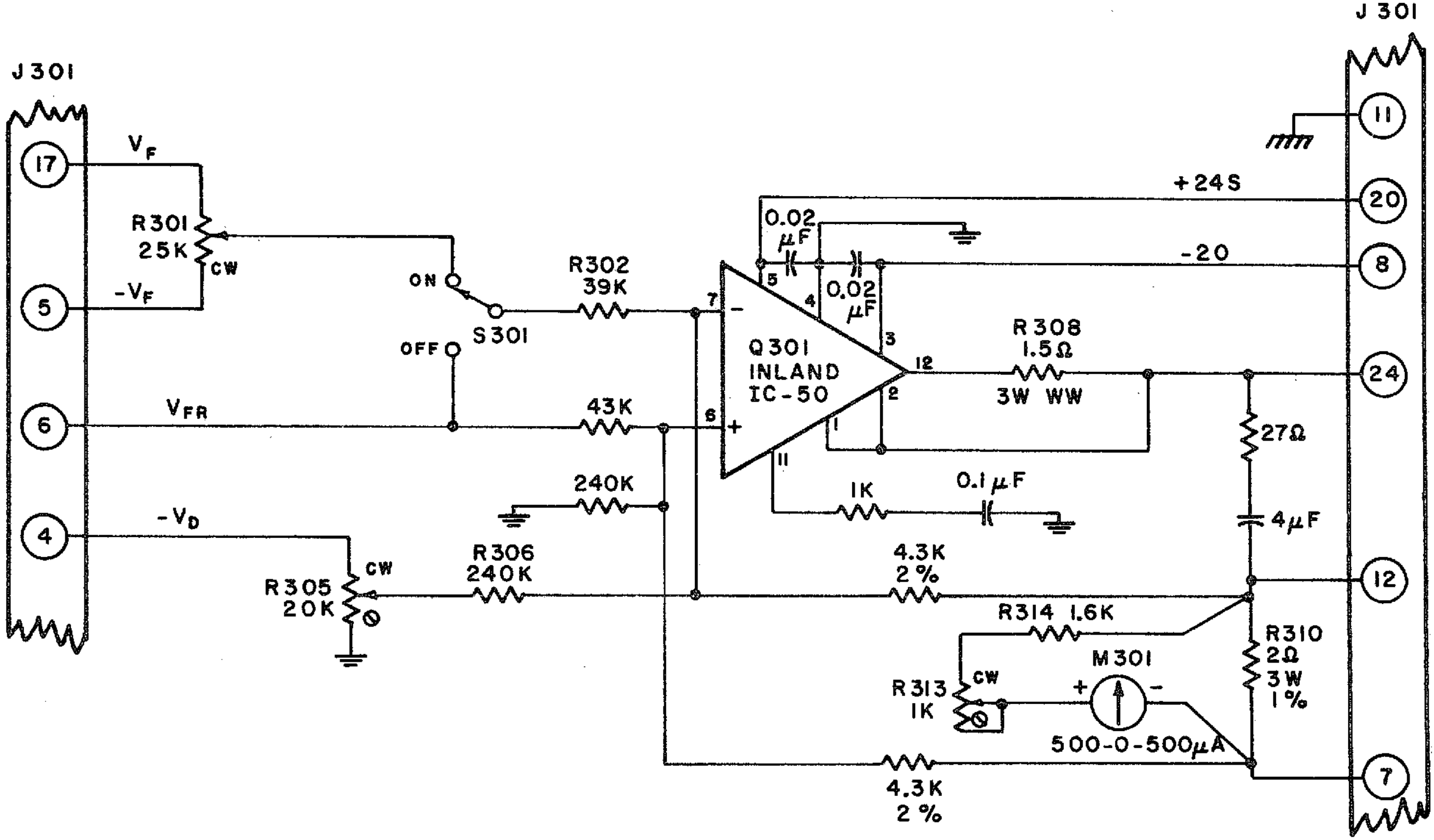


Fig. F-6 SCHEMATIC CIRCUIT DIAGRAM OF TENSION-CAPSTAN CONTROL PANEL

oz-in/volt. To make the net useful output torque of the motor proportional to amplifier input voltage in the presence of bearing and brush/commutator friction drag, a small offset input giving rise to a torque equal to the drag torque is provided through R306 and set with R305. Resistor R308 sets the peak amplifier output current limit at about ± 0.595 amperes which, in turn, limits peak motor torque to ± 6.19 ounce-inches. Sensitivity of meter M301 is set with R313 and R314 to produce an indication of 500μA (full scale) when the motor is developing a torque of 5 ounce-inches to facilitate direct reading of total torque.

Tension-Command Exciter (Figure F-7)

Operational amplifier Q120 (Fairchild Type μA741TC) is connected as an inverting amplifier with a voltage gain (from junction of D120 and R120 to pin 6 of Q120) of -6.5. In the standby mode when the tape is not moving, the input from Q14A is "low" (less than +0.3 volt), so due to the threshold of D120, the input voltage to Q120 is zero and its output is zero. On the other hand, in either the record of play mode, or in the standby mode while the tape is still moving, the input from Q14A is "high" (greater than +2.4 volts), so due to the voltage drop of D120, the input voltage to Q120 is at least ± 1.75, and its output voltage tends to go to at least -11.4 volts. However, zener diode D121 acts as a feedback limiter to hold the amplifier output at -10 volts. By virtue of the input and overall feedback resistors R175 and R133 respectively, the three operational amplifiers Q123, Q124, and Q125 (each Fairchild Type μA741TC) behave under steady-state conditions as a single operational amplifier connected as a unity-gain inverter (gain trimmed with R126) to produce an output, V_F, at pin 6 of Q125 which is equal in magnitude but opposite in polarity to the output of Q120. Thus, the steady-state values of V_F are either zero or +10 volts.

Operational amplifier Q125 is connected as a unity-gain inverter, so the output of Q124 is simply $-V_F$. Operational

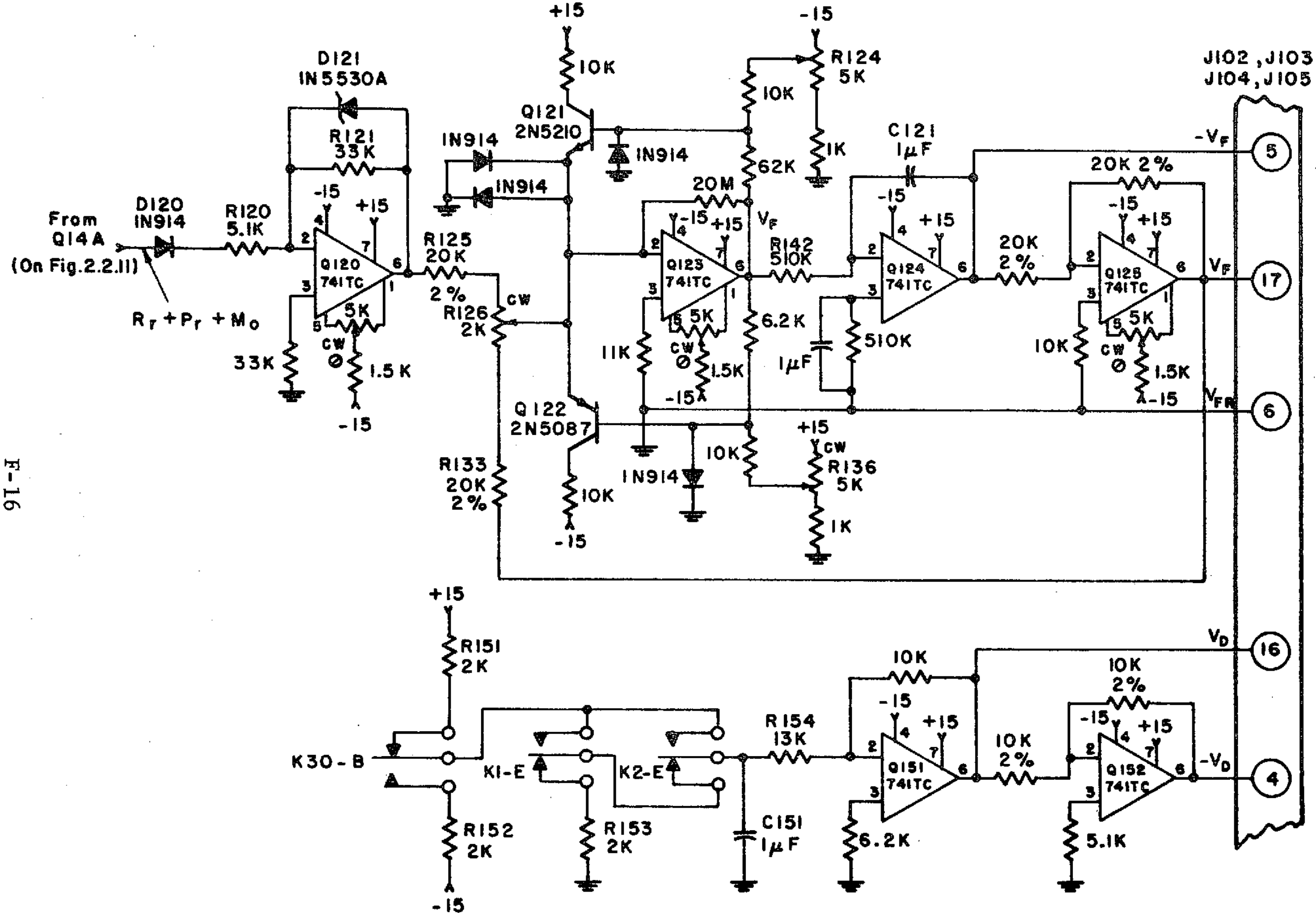


Fig. F-7 SCHEMATIC CIRCUIT DIAGRAM OF TENSION-COMMAND AND DRAG-COMPENSATION EXCITERS

amplifier Q124 is connected as an inverting integrator with a gain of about -2 per second, so the output of Q123 is $0.5\dot{V}_F$. Thus the maximum rate at which V_F can change is established by limiting the output voltage of Q123. This action is performed by a pair of active feedback limiters consisting of Q121, Q122, and their associated components. Variable resistor R129 permits adjusting the voltage limit of Q123's output from about +2.4 to +10.3 volts, which corresponds to V_F rates from 4.8 to 20.6 volts/second; while variable resistor R136 permits adjusting the opposite-polarity limits over the same ranges.

Drag-Compensation Exciter (Figure F-7)

Relay contact K30-B (Figure F-7) is operated when the tape is moving forward, is released when the tape is moving backward, and may be in either state when the tape is stationary. Relay contact K1-E is operated in the record mode, relay contact K2-E is operated in the play mode, and both K1-E and K2-E are released in the standby mode. Resistor R154, in conjunction with either R151, R152, or R153, depending on the states of the relay contacts, serves as the input resistor of operational amplifier Q151 (Fairchild Type μA741TC) which is connected as an inverting amplifier with a gain of -2/3. Thus in the record mode with the tape moving forward, the effective input voltage (via R152) is -15 and the output of Q151, V_D, is +10 volts; in the play mode with the tape moving backward, the effective input voltage (via R151) is +15 and V_D is -10 volts; and in standby, the effective input voltage (via R153) is zero, so V_D is zero. Operational amplifier Q152 (Fairchild Type μA741TC) is connected as a unity-gain inverter to produce an output of $-V_D$.

Power-Off Dynamic Braking

The power-off shorting action is readily provided by normally-closed contacts on the main power relay, K170, but since only the supply-reel motor is to be shorted and the tape can be moving in either direction when power is lost, it is

necessary to also have a nonvolatile memory of tape direction to permit shorting, the proper reel motor. This memory is provided by using a magnetic-latching type relay (Automatic Electric Series HRM, number HF-26) for K30, which performs all direction-related switching. The power-off dynamic braking is provided by relay contacts K170-E, K170-F, K30-D and K30-E connected as shown schematically in the upper-right corner of Figure F-10.

Mode Control System

A schematic of the mode control system is shown in Figure F-8. Inputs from the left and right end-of-tape sensors appear at pins 7 and 25 respectively of J106. Shunt capacitors C1 and C2 suppress pickup in the cable of "hash" from the four DC drive motors. Cascaded inverters Q11B and Q110 (each 1/6 of a type 7404) in conjunction with positive feedback through R1 act to "square up" the output from the left end-of-tape sensor to produce standard logic-level signals T_L and $\overline{T_L}$. Inverters Q11A and Q11C with R2 perform the same function for the right end-of-tape sensor to produce T_R and $\overline{T_R}$. Two-input NAND gate Q6D (1/4 of a type 74L00) combines T_L and T_R to produce the $\overline{T_L T_R}$ signal which (via circuitry shown on Figure 2.2.13) electrically locks up the main power relay under normal conditions, and shuts off all power under abnormal conditions that cause T_L and T_R to be high at the same time. Cross-coupled two-input NAND gates Q1A and Q1B (each 1/4 of a type 74L00) form the left end-of-tape memory or latch, having outputs M_L and $\overline{M_L}$; while Q3A and Q3B (each 1/4 of a type 74L00) similarly form the right end-of-tape latch, having outputs M_R and $\overline{M_R}$.

Record-mode relay K1 is energized by transistor Q26 and its associated circuitry when the output from NAND gate Q14C (1/3 of a type 74L10) is high; and play relay K2 is similarly energized by Q25 and its associated circuitry when the output of NAND gate Q14B (1/3 of type 74L10) is high. When either of these relays is energized, it is electrically locked up through its driving logic by the signal (R_r and P_r respectively) derived

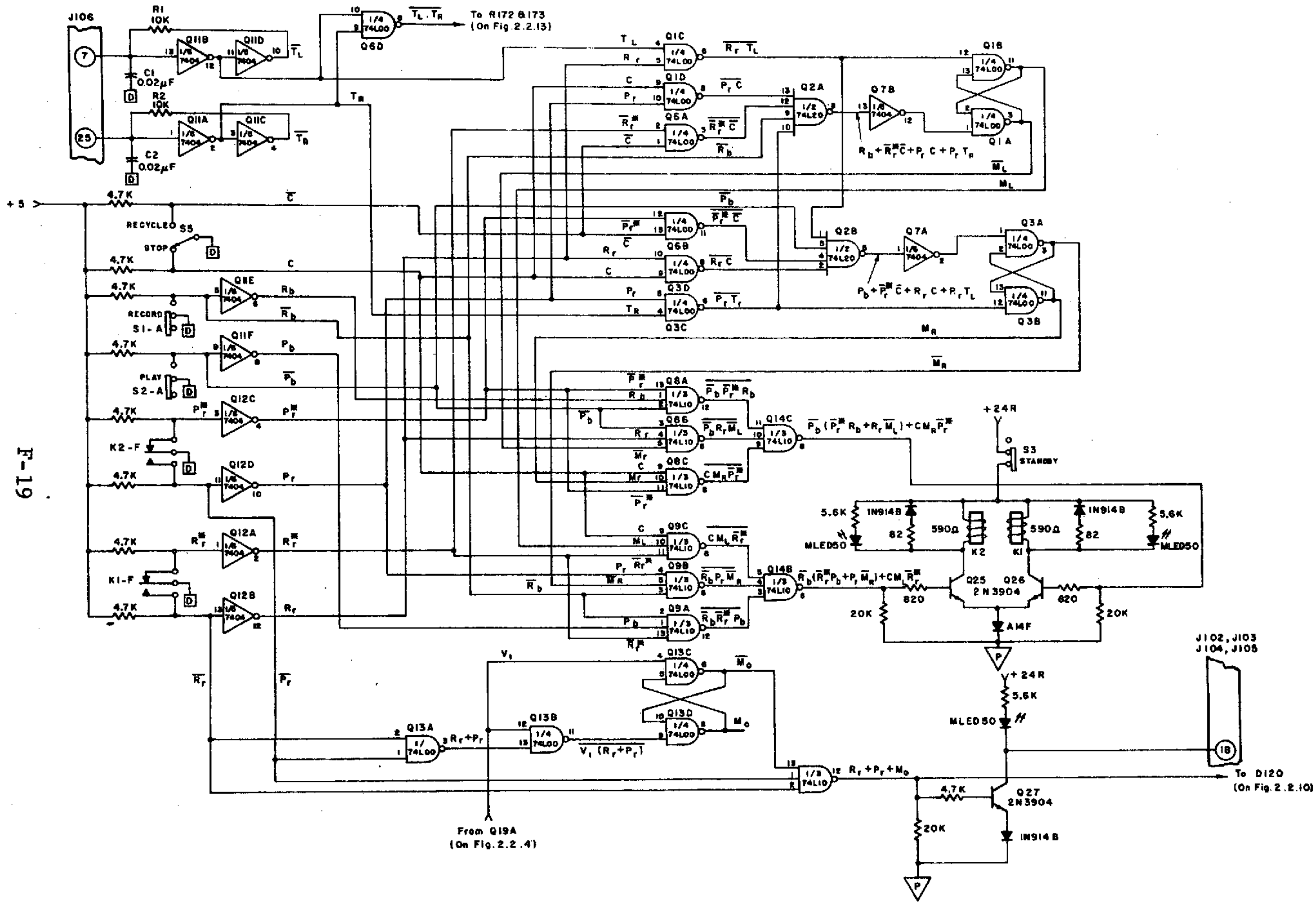


Fig. F-8 . SCHEMATIC CIRCUIT DIAGRAM OF MODE-CONTROL SYSTEM

from its own F contact. Thus, pressing the normally-closed standby push button, S3, in the relay supply line causes whichever relay is locked up to release.

Cross-coupled two-input NAND gates Q13C and Q13D (each 1/4 of a type 74L00) form the operate memory or latch, having outputs M_0 and $\overline{M_0}$. The latter output is combined with the $\overline{R_r}$ and $\overline{P_r}$ signals in NAND Q14A (1/3 of a type 74L10) to produce the $R_r + P_r + M_0$ signal which drives the tension-command exciter (see Figure 2.2.10) directly, and relay K401 (via pin 18 of J104) on the speed-control panel (see Figure F-1) through transistor Q27 and its associated circuitry.

Transport Circuitry

A complete schematic circuit diagram of the transport, including the head, is shown in Figure F-9. Each of the four motors is shunted by a 0.02μF disk ceramic capacitor to suppress electrical "hash" produced by the brush/commutator switching actions. Inverters Q601C and Q601D (each 1/6 of a type 74R04) are used as a line drivers at the outputs of the tachometer. Shunt resistors R601 and R602, and capacitors C601 and C602 are used on the outputs of these inverters to eliminate the effects of cross coupling of the $\overline{A}$ and $\overline{B}$ signals in the output cable, and to suppress pickup of "hash" from the motors. The outputs of the two tension-sensing instruments are plugged into miniature phone jacks J603 and J603 to facilitate routing these signals back to the main control panel via the cable plugged into J601.

Power System (Figure F-10)

Diode D172 prevents the main power relay, K170, from being energized unless the input supplies have the proper polarities, while 20-volt zener diode D171 prevents K170 from being energized unless both input supplies are present. If the input supplies are proper, pressing the "on" push button, S170, will energize

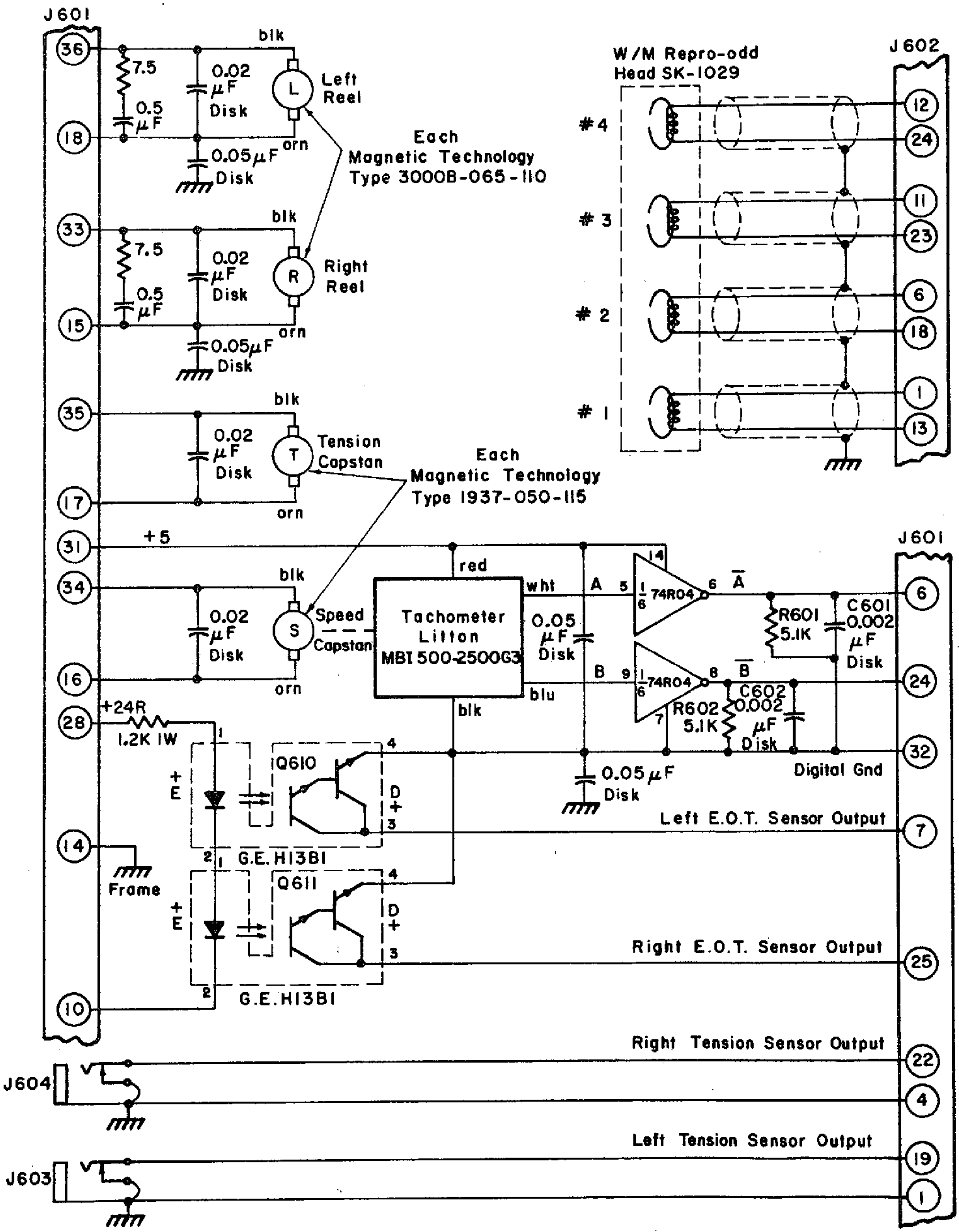


Fig. F-9 SCHEMATIC CIRCUIT DIAGRAM OF TRANSPORT

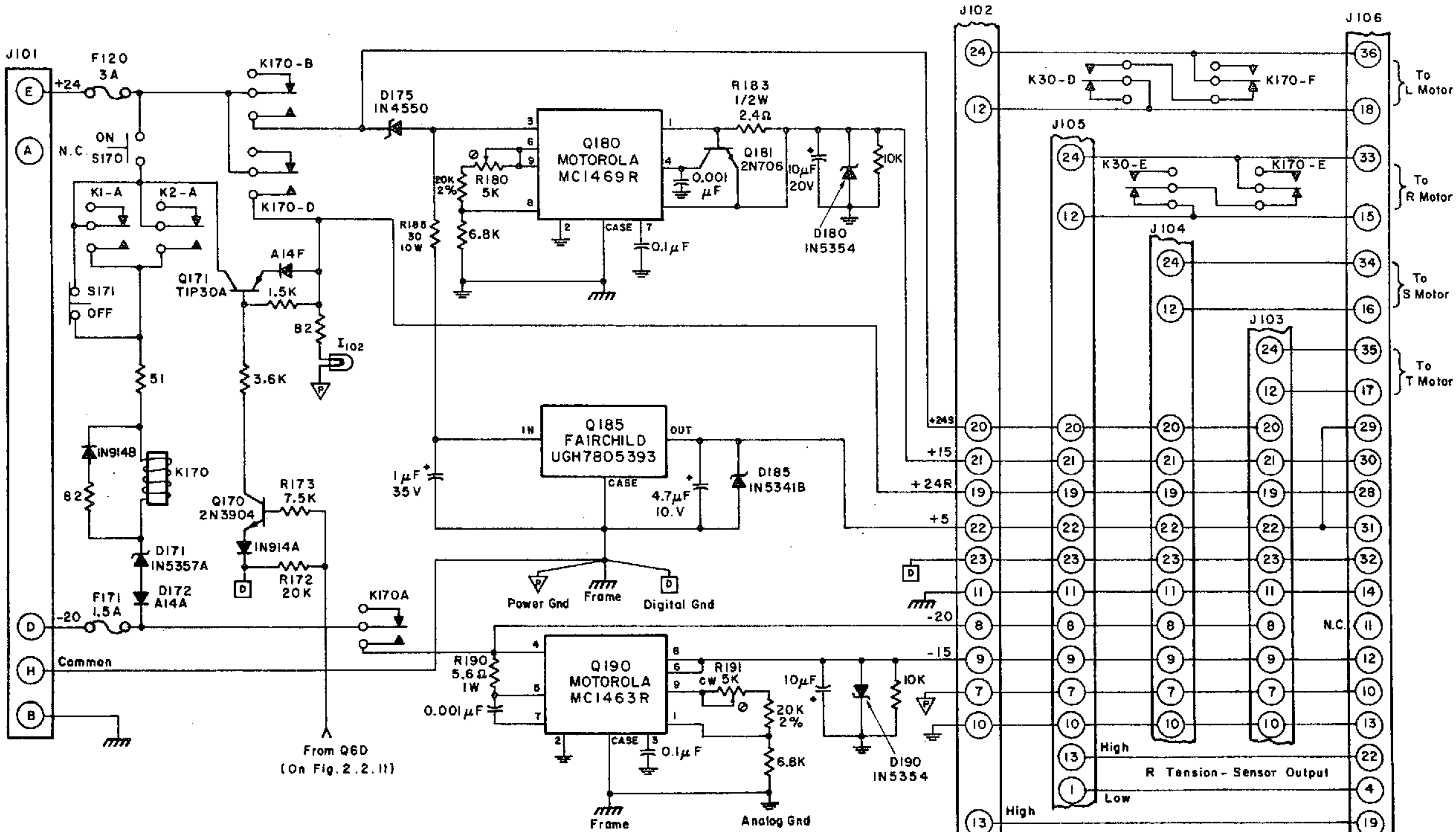


Fig. F-10 SCHEMATIC CIRCUIT DIAGRAM OF POWER SWITCHING, REGULATORS, AND DISTRIBUTION

K170. When the relay operates, its K170-B contact applies +24 volts to the power amplifiers, the +15 volt regulator, Q180, and the +5 volt regulator, Q185; its K170-D contact applies +24 volts to lamps and other relays; and its K170-A contact applies -20 volts to the power amplifiers and the -15 volt regulator, Q190. If the tape is in its proper position through the end-of-tape sensors, transitor Q171 then will be immediately saturated, via transistor Q170, by the high signal from Q6D (see Figure F-8) to effectively shunt S170 and keep K170 energized when S170 is released (i.e. K170 becomes electrically locked up). With S170 released, K170 will release and remove all power if the signal from Q6D ever goes low. The normally-open contracts K1-A and K2-A of the record and play relays respectively parallel the normally-closed "off" push button, S171, in series with K170 to prevent the pressing of S171 from releasing K171 in either the record or play modes.

Resistor R180 permits setting the output voltage of regulator Q180 to +15 volts, and R183 in conjunction with transistor Q181 sets the load-current limit at about 240 mA. Similarly, R191 permits setting the output voltage of regulator Q190 to -15 volts, and R190 sets the load-current limit at about 210 mA. The 17-volt zener diodes D180 and D190, and the 6.2-volt zener diode D185 do not conduct under normal conditions and serve only to protect all of the semiconductor circuitry connected to the +15, -15, and +5 volt lines respectively from over voltage or reverse voltage due, for example, to regulator failure or inadvertent shorts between supply lines.